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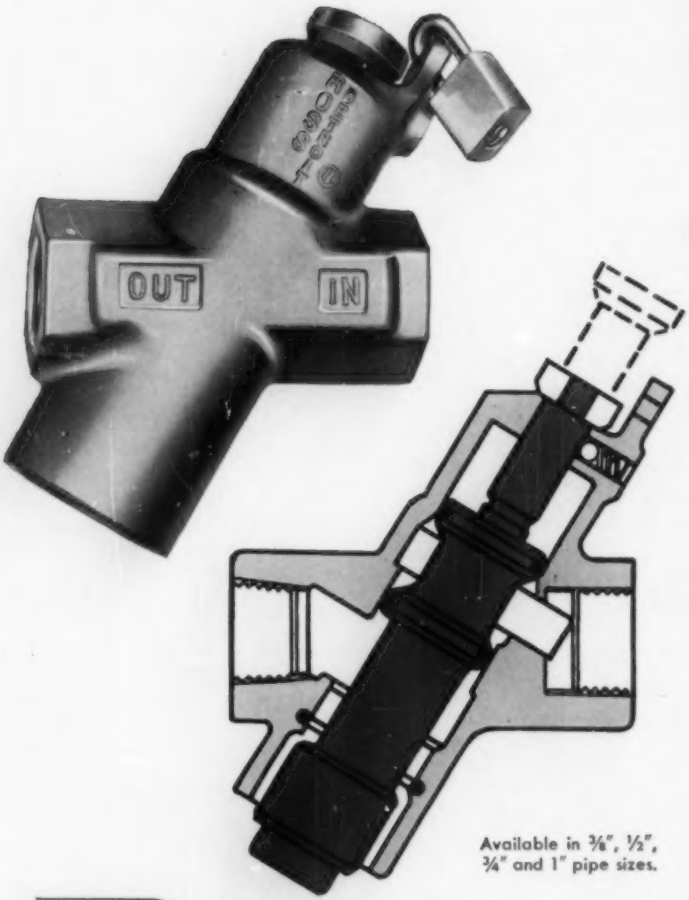
PRODUCT ENGINEERING

McGRAW-HILL WEEKLY OF DESIGN, RESEARCH AND DEVELOPMENT · JUNE 27, 1960

THE SIGNIFICANCE OF Wk^2 AND HOW TO CALCULATE IT

... see page 3

Lock out air for machine repair



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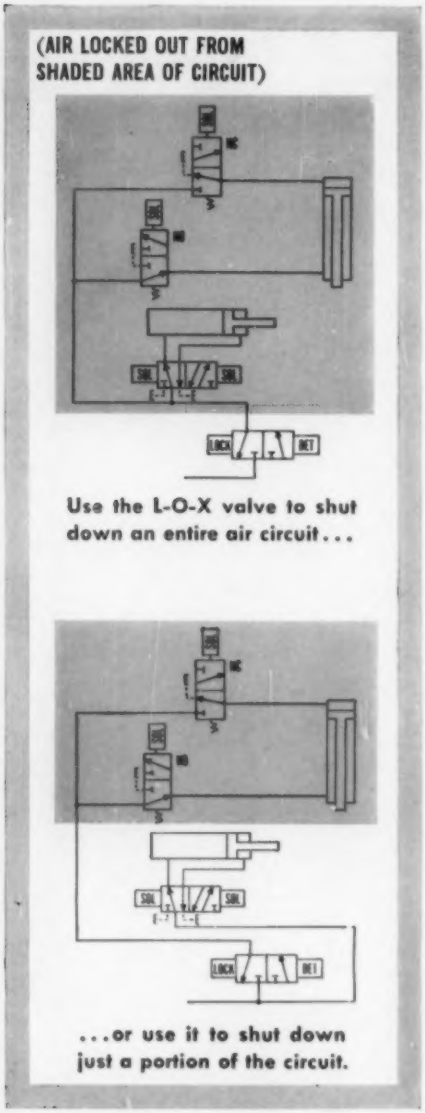
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Use the L-O-X valve to shut down an entire air circuit . . .
. . . or use it to shut down just a portion of the circuit.

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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY OF DESIGN, RESEARCH AND DEVELOPMENT

June 27, 1960 Vol. 31, No. 26

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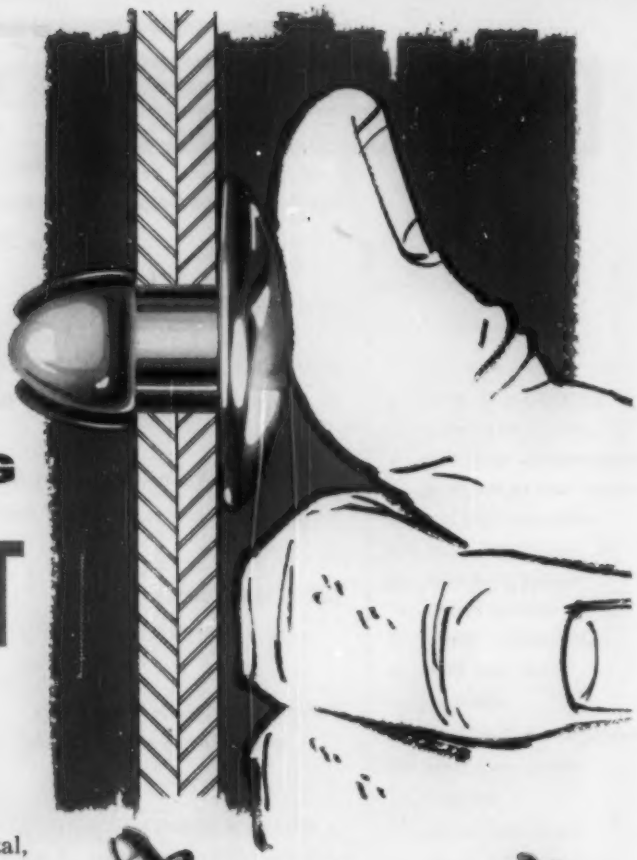
to fasten
panels
or parts . . .



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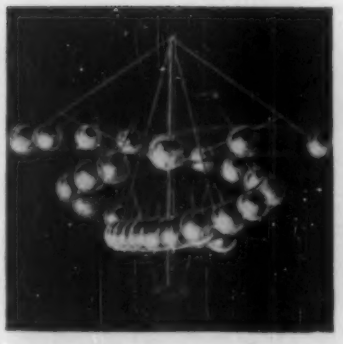
INTERESTING TO NOTE



On our cover, the familiar ball governor goes from rest to full speed in one revolution. As a practical matter, no governor will ever accelerate that rapidly —the engine masses just couldn't be moved that fast. But accelerations do occur and, as in most rotating equipment, it is these transients that cause all the trouble. That is why we are printing the latest revision of "The Significance of *Wk*^{2}" (see page 39)—expanded, brought up to date, and still as basic a design guide as ever it was.

Tobacco—Gift from the New World

An interesting new book, *Tobacco and Americans*, by Robert K. Heimann reveals that Americans spent more than 6½ billion dollars for tobacco products in 1958. If you want a comparison, this is better than twice the amount we spent on education. Of the 425 billions of cigarets sold, many were dispensed from that intricate engineering marvel, the vending machine (see story on page 48). Although the demand for tobacco now increases yearly, there was a time when it was an unwanted commodity.

When Columbus reached the shores of San Salvador, he was greeted by natives bearing fruit, wooden spears and "certain dried leaves" which emitted a distinct fragrance. Columbus' crew welcomed the spears and fruit; the dried leaves they threw away. Several days later, they encountered a native in a canoe a good many miles from shore. Besides bread and water, the Indian carried some of those dried leaves. The following month two Spanish sailors on a three-day reconnaissance of Cuba found Indians smoking the same mysterious "dried leaf." This time the Spaniards imitated the natives—and became the first Europeans to smoke tobacco. In the islands off Cuba, natives inhaled a mixture through a hollow Y-shape tube called a "taboco" or "tobago"—hence the word tobacco. The Quiche-Mayans were fond of tobacco leaves rolled in the form of our present-day cigar—their word for tobacco was "zig" and for smoking, "zikar." Soon Spanish, Portuguese and British explorers were bringing tobacco home with them, and before long it was being heralded as a health cure-all. While physicians were listing it as a cure for almost every known disease, skeptics considered it a cause of almost every known disease. The health factor of tobacco has remained a controversy for the past 400 years.

The Galvanometer Named Cavendish

Today, oxidation is well understood. High school chemistry pupils study about it; engineers put it to work as a coating for certain product designs (p 31). Yet several centuries ago, the oxidation reaction was as unknown as oxygen itself. That was before Henry Cavendish. It was in the late 18th century that this Englishman made

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a startling discovery about one of the best known oxidation products—water.

At the time, water was thought to be an element. (The Bible says it was a basic liquid, made on the first day of Creation.) For several years, Cavendish studied water, using static electricity as one of his laboratory tools. Then, in 1781, he built a large globe to study the effects of static electricity upon other liquids and gases. In one of these experiments, he filled his globe with five parts of air and two parts of a gas (hydrogen) obtained by dissolving a metal in acid. Next, he applied an electric spark. There was a sharp report. Cavendish observed that some of the air still remained; he also noticed beads of moisture on the walls of the globe. He tested the liquid but could only detect traces of nitric acid.

He repeated the experiment, this time using some of Priestley's newly discovered oxygen in place of air. The electric spark produced a loud bang. This time, when the mysterious liquid within the globe was analyzed, it was pure water. Cavendish had made one of the most fundamental discoveries in the history of science; he had proved water is not a basic element.

After the death of Cavendish one of the mysteries of his experimentation was solved. He said he used uniform electrical charges to trigger all of the reactions. Physicists had wondered how he was able to estimate the strength of these charges before the invention of the galvanometer. Electrical pioneer James Clerk Maxwell found the answer many years later when he studied Cavendish's notebooks. Said Maxwell, "Cavendish was his own galvanometer. In order to compare the intensity of circuits he caused them to pass through his own body, and by comparing the intensity of the sensations he felt in his wrists and elbows he estimated which of the two shocks was the more powerful."

Keeping Cool 25 Miles Up

It was less than a century ago when a group of Midwestern preachers were telling their congregations that the world would soon come to an end, because man had invented all there was to invent. Now, scientists and engineers face some of the greatest challenges in history, including design for outer space.

In the mid-1950s, true space flight had yet to be accomplished, but a young Air Force doctor, Lt David Simons, was given the assignment to investigate the threshold of space by sealing himself into a capsule and going aloft some 100,000 ft suspended from a helium-filled 0.002-in.-thick polyethylene balloon. As Simons relates in his recently published book, *Man High*, one of the most critical problems faced in designing the capsule was controlling temperature. Since the gondola's surface temperature at 100,000 ft would climb to nearly 200 F during the day, then drop to −85 F at night, a small, lightweight air conditioner-heater had to be designed. The problem was solved by a simple water-and-fan device. A container of water (which boils at 32 F at 112,000 ft) was vented to the outside of the cabin. During the day, the fan transferred Simons' body heat to the container. The water boiled, thus dissipating the heat and maintaining a comparatively cool cabin temperature. At night, Simons simply shut off the device and let his body heat keep the cabin warm.

—Benedict A. Leerburger Jr

NEXT WEEK IN PRODUCT ENGINEERING

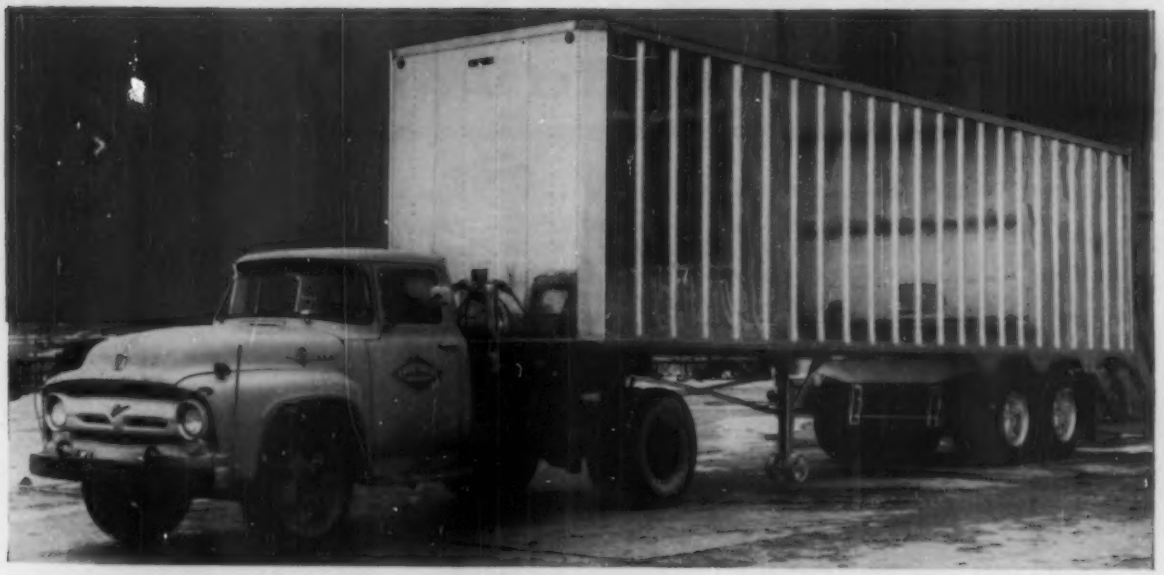
. . . **Demagnetize Before Assembly**
Machine parts accidentally magnetized during fabrication can create a variety of troubles in the finished assembly.

. . . **Solid Aluminum Bearings**
To minimize starting friction and prevent seizure, successful application depends on proper selection of material.

. . . **Getting Your Share From Technical Literature**
A technical librarian shows how to solve engineering problems in the library.

. . . **Determining Focal Length of a Thick Lens**
For engineers who do occasional optical work without access to optical equipment.

. . . **Today's Chrome Plate Finishes**
An expert relates the new finishes to the old.

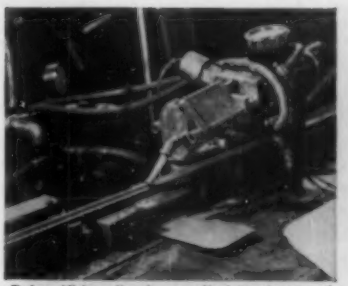


How FRUEHAUF rolls 'em out stronger, lighter

...with adhesives based on THIOKOL polysulfide polymer

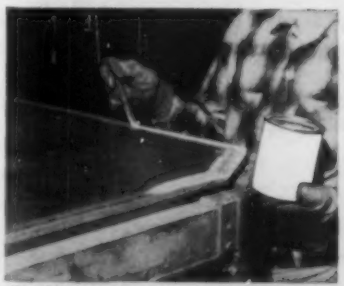
Fruehauf Trailer Company adapts the unique bonding action of polysulfide liquid polymers in a unique way. Polysulfide-base compound is used to join 1-piece roof top to roof bows. Result: roof span is lighter, stronger, and completely weathertight. Rubbery cushion between roof and structural members helps absorb shock of road travel. The use of polysulfide, for the first time, permits bonding of bows and roof sheet for greatly increased structural strength. This is another outstanding example of the industrial applicability of adhesive and sealing compounds properly formulated with THIOKOL polysulfide polymers—and of the benefits that accrue.

For further information about how THIOKOL polysulfide polymers serve industry, and how they may help you—write to THIOKOL on your letterhead.



Polysulfide adhesive applied to structural cross-members by machine.

Cross-members held in place to trailer top sheet by cured sealing compound.



Providing extra seal at roof corners by brushing on polysulfide-base compound.

Skylights also sealed with polysulfide-type sealants as added precaution to guarantee complete weather-tightness.

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Not all polymers are polysulfide. When purchasing adhesives or sealants, be sure to specify THIOKOL polysulfide-base sealants. THIOKOL makes only the polysulfide polymer, not the finished product.

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DEVELOPMENTS TO WATCH...

Sparks can harden titanium, British report

Spark treatments show considerable promise as a means for increasing the surface hardness of titanium, and may prove useful on other nonferrous metals, says a British report relayed by Imperial Chemical Industries.

Electrical sparks, produced by the make-and-break contact of an electrode vibrating against the workpiece, melt tiny bits of metal which chill and harden rapidly when the discharge is interrupted.

Micro-hardness values as high as 2000 V.h.n. have been obtained, with the average figure being about 1450.

Oxygen does not appear to enhance this effect. Sparking in an argon-oxygen mixture did produce surface oxides; but average hardness was only 1350 V.h.n. and the maximum obtained was 1420.

Titanium can also be carbonized by sparking, the report says—either by treatment in air (with a graphite electrode) or by performing the operation under paraffin oil. Here, hardnesses as high as 2700 V.h.n. have been obtained.

Boiling sulfur will cool new reactor

With vaporized metals already being widely tested as coolants for nuclear reactors, sulfur is now to have its chance. Aerojet General Nucleonics is exploring the possibility for the AEC, and says preliminary investigation indicates sulfur, in a binary vapor cycle similar to the mercury topping cycle in mercury vapor powerplants, will have a number of advantages. Not the least of these is high thermal efficiency (over 50%).

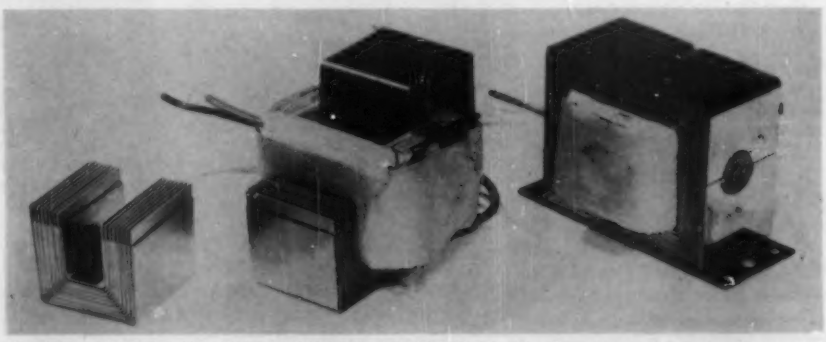
The system can operate at low pressure (185 psig), permitting use of mild steel only 1.25 in. thick for the pressure vessel, and on a superheated steam cycle (850 F, 1200 psia) that permits use of standard steam plant components.

A test loop has been constructed to study corrosivity of liquid and vaporized sulfur, and provide detailed data on heat-transfer characteristics.

New transformer design slashes size and weight

Transformers as much as ½ smaller in size than conventional units, and offering a freedom in design "never before obtainable" are promised by Sylvania Electric Products Inc, Ipswich, Mass as a result of a new core design it has developed. In place of laminations with the standard "E" and "I" shape, it is using U-shape formed metal parts (see photo). These, Sylvania says, can be nested and stacked in almost any desired configuration, making it possible to design transformers in a wide variety of shapes and in any size up to 18x18x36 in.

Furthermore, says Sylvania, the new laminations get around the problems of electrical interference that characterize the E-I lamination alternate stacking system. With the new design, the magnetic lines of force flow with, rather than across, the grain of the steel, resulting in increased rather than decreased magnetic flow. It is this which permits the size and weight reductions. —ARG



NESTED, INTERLOCKING U-SHAPED ELEMENTS take the place of standard E and I laminations in new Flexicore transformer design.

and they run
and they run
and they run

1903—
Indianapolis.
a trolley car.
a rolling adventure surrounded by noise.
pennies, nickels, children . . .

and inside—
a Fairbanks Morse electric motor.
it drove the trolley over thousands of miles
and rode with it
into glorious retirement.

pick a year—
from the turn of the century until now.
pick a month,
pick a day,
pick a city,
pick a town—
our motors are in its history . . .
pulsing, driving, working.
powering the things we need
and the things we want.
pushing our daily advances.
pulling us into the future.

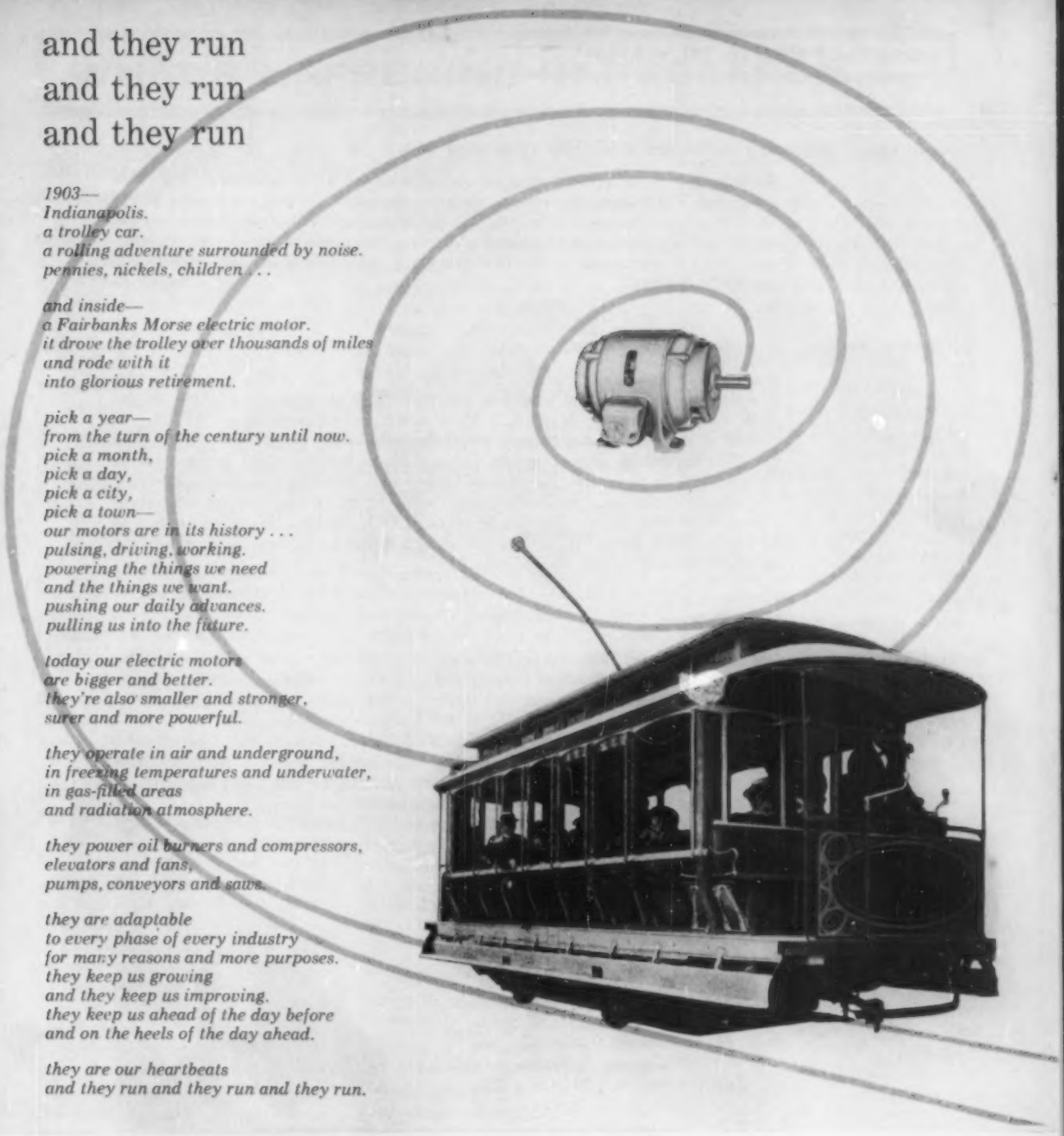
today our electric motors
are bigger and better.
they're also smaller and stronger,
surer and more powerful.

they operate in air and underground,
in freezing temperatures and underwater,
in gas-filled areas
and radiation atmosphere.

they power oil burners and compressors,
elevators and fans,
pumps, conveyors and saws.

they are adaptable
to every phase of every industry
for many reasons and more purposes.
they keep us growing
and they keep us improving.
they keep us ahead of the day before
and on the heels of the day ahead.

they are our heartbeats
and they run and they run and they run.



Fairbanks, Morse

A MAJOR INDUSTRIAL COMPONENT OF **FAIRBANKS WHITNEY CORPORATION**

The electric motor is one of the most versatile sources of power ever developed. It is economical, practical and time-resistant. Fairbanks-Morse electric motors can turn out ⅓ horsepower or 10,000 horsepower, meet every known job demand within this range or be custom-specified to your blue-print projections. Whatever your production needs or plans may be, our electric motors can power them.

If you are in a field where power for production must be efficient, effective and dependable—we suggest that you consider our great variety of electric motors. For further information please write to: Mr. George H. Herrick, Vice President and General Manager, Electrical Division, Fairbanks, Morse & Co., Freeport, Illinois.

CIRCLE 7 ON READER SERVICE CARD

New rotor assembly achieves 450,000 rpm and more

Shaft speeds above 450,000 rpm are being achieved in an air-driven rotor, New Hampshire Ball Bearings Inc reports, using miniature bearings and a new rotor design. The rotor, engineered by Fairfax Mfg Co for a hand-held industrial grinder, requires only 100-psi air pressure and accelerates to operational speeds within 2 sec. Development work is continuing at the two companies, with "an additional 200,000 rpm expected to result."

Vacuum melting provides tougher steels

Vacuum melting is more effective than variations in either carbon content or heat treatment for increasing the toughness and ductility of ultrahigh-strength 5% chrome steels, say J. C. Hamaker, Jr and E. J. Vater in a report prepared for the ASTM.

Tests of steels developing ultimate tensile strengths in the 220,000-psi range showed that modification of carbon content (from 0.20 to 0.50%) could increase tensile strength; but, in every test, the vacuum melted steel "exhibited marked superiority." The ductility value and true fracture stress achieved by vacuum melting were about equivalent to what might otherwise be obtained by a reduction in carbon content of 0.14%, while the impact strength of the vacuum-melted metal was considerably above all values obtained by the other means.

New process bypasses sintering

Crystalline materials that can be fabricated into rods and similar shapes simply by vibratory compacting instead of pressing and sintering are being produced by Spencer Chemical Co. The secret: a new "arc fusion" process which gives a crystalline rather than a ceramic product.

First application—and primary aim of the development—is to the heavy-element oxides and carbides (urania, thoria, uranium monocarbide, uranium dicarbide) used for nuclear fuel rods. Here, Spencer confidently predicts, the new crystalline materials will produce a superior product—denser and more uniform—at lower cost.

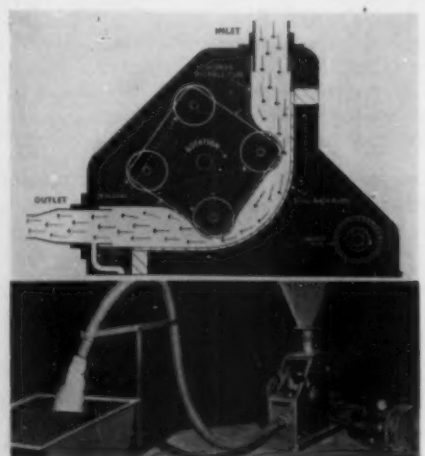
Spencer has not yet investigated other possible applications for the process; but it could pave the way for low-cost fabrication of a good many other ceramic-type materials.

Rollers push solids in new squeeze-type pump

Another solids pump based on the flexible-tube-and-roller principle (*PE*—Dec 14 '59, p 11) has been designed in England. This one is being introduced by Henry Simon Ltd, Cheadle Heath, Stockport. It will convey "practically any solid material that can be fluidized by air" at delivery rates to 8000 lb/hr. Total conveying lengths to 200 ft and vertical lifts to 70 ft are possible.

Since the rotor supplies the power to squeeze material through the tube, only a minimum amount of air is required. Furthermore, no damage is done if the pump runs dry.

In the initial model, offered with 2-in. or 3-in. tubing, pump dimensions are 17x47x37 in., and a 1-hp motor is used. (For more on flexible-tube pumps, and a comparison with other types used for liquids, see *PE*—June 6, p 42.)—ARG



FLEXIBLE-TUBE PUMP features low air requirement and long-distance conveying. Diagram shows tubing and 4-roller rotor; photo, a typical setup.

WHAT'S HAPPENING IN RESEARCH . . .

Clue to improved soft magnets

A finding that may pave the way to better soft magnetic alloys is contained in a report relayed by Powder Metallurgy Ltd of England.

The report deals with a method for producing such alloys in strip form by standard powder metallurgy techniques and by direct rolling of the powders. The primary aim was to reduce the danger of contamination by carbon, sulfur and phosphorus, and of oxidation that occurs when conventional methods (melting, hot rolling, packing) are used for producing the strip.

But, in addition, it was found, in experiments with Mumetal (nickel-iron core material) that, at the upper limits of Cu, Fe, Mn and Mo contents, the initial permeability is still on the increase. This should make it possible to raise that factor by further adjustment of alloy content.

The work was done by H. H. Scholefield and S. G. Richardson of Telegraph Construction & Maintenance Co Ltd, England.

New studies seek hidden factors in heat conductance

The conductance of heat across apparently identical joints may vary by a factor of 2 or 3, even in specimens prepared under controlled laboratory conditions, M. E. Barzelay of Syracuse University reports. With different types of connectors, the variation in heat conduction across an aircraft-type skin-stringer joint may be as great as 25 to 1.

To find out why, he's been making a long-term study of various types of joints under controlled conditions. In the most recent series of tests, involving more than 100 aluminum-alloy and high-temperature-alloy structural-joint specimens, he found fastener type has a significant effect. Alloy steel screws, high-shear pins, and lockbolts give the highest interface conductance; blind rivets and exploding-type rivets, the lowest in most cases.

The rate of heat flow into the specimen also has a pronounced effect on interface conductance; and, in specimens with a sandwich material at the interface, the good conductors give high interface-conductance values. However, Barzelay says "factors other than the thickness and conductivity of the sandwich material appear to be significant."

Surprisingly, cleanliness of the joint does not seem one of such factors.

Reports on the tests—part of a continuing program sponsored by NASA—are available from that agency. The latest is Technical Note D-426.

New glossary explains plasmas and electron devices

A new special dictionary—this one on plasma physics— is the second in what promises to be an extremely valuable series of collections of new words in science. This one, like the first, on solid state physics (*PE—Feb* 29, p 9), was prepared by the American Institute of Physics for a science writer's symposium. Like the first, too, the new one is being made available to PE readers without charge as long as supplies last.

Glossary of Terms in Plasma Physics is a 30-page printed booklet covering about 150 terms and concepts, including beta and Boltzmann factors, collision parameters, Debye length, Kirchoff's Law, and such widely used terms as ionization, Mach number, and ohmic heating. Copies may be obtained by writing to Eugene Kone, AIP, 335 East 45th St, New York 17.

How gases move through solids

Tradition has it that metals are impermeable to gases except where porosity exists. But recent studies indicate this is not so.

Gases can and will diffuse through "solid" metal, at least under the influence of heat and radiation.

Researchers at Harwell in England and the AEC's Hanford Works in the US have found that argon, krypton, and xenon will diffuse through silver. Other studies show definite evidence that helium will diffuse through aluminum when it is introduced to the metal by ion-bombardment techniques.

The diffusion mechanism is not yet entirely clear. But new AEC-sponsored research is now being aimed in this direction.

A report, prepared by G. T. Murray and G. Pincus of Materials Research Corp, summarizing previous work, is being made available through OTS, Dept of Commerce, Washington 25, DC (28 pages; price, $1).

Liquid metals tested for high-temperature cells

Can a reversible high-temperature galvanic cell be developed, using liquid alloy as the electrolyte? U of Chicago researchers are trying to find out. Efforts to base such a design on gallium have not been successful, but tests of solutions made by dissolving cadmium, thallium, lead and bismuth in gallium indicate that one of these may prove to be a workable, practical combination.

Another possibility: antimony or aluminum dissolved in liquid iodine. Liquid iodine itself is an electrical conductor, the U of C researchers point out, and both of these increase its electrical conductivity. Surprisingly, tin and indium decrease it.

briefs . . .

Lower prices for rare-earth metals should encourage research applications for these "new" materials (*PE—Apr* 25, p 40). Among the recent reductions are these, announced by Research Chemicals Div, Nuclear Corp of America: Praseodymium to 50¢/gm in 100-gm lots; neodymium to 40¢, samarium to 50¢, gadolinium to 75¢, terbium to $3.75, dysprosium to 75¢, holmium to 80¢, erbium to 80¢, ytterbium to $1.25. Previous prices for all these rare-earth metals were 10 to 50% higher.

The tungsten-rhenium thermocouples developed in England (*PE—Oct* 19 '59, p 11) are now to be marketed here by Englehard Industries. These are thermocouples designed for use at temperatures to 5000 F in vacuum or reducing atmospheres. In oxidizing atmospheres or in the presence of hydrocarbons, though, the susceptibility of tungsten to attack limits their application. —ARG

FROM WASHINGTON . . .

Nuclear power development hits road-block

Development and construction of 7 or 8 nuclear powerplants—the equipment and facilities supposed to keep the US ahead of the world in atomic power—have been given a hard blow by a US Court of Appeals.

It has found that the Atomic Energy Commission is misreading the Atomic Energy Act when it permits a firm to go ahead with construction before the AEC certifies that the finished plant will be safe to operate. Purpose of this AEC procedure is to get a plant into operation sooner—by giving the company the 4 or 5 years of construction time to perfect its design and safety features. Under present AEC procedure, the firm still needs a separate operating permit before the reactor can be turned on.

The court case involves the $55-million Power Reactor Development Co—a Michigan corporation including 14 public utilities plant—now about 60% completed on the outskirts of Detroit. **Three labor unions convinced the Appeals Court that their reading of the AEC basic law is that the commission is required to make a decision on safety before any construction permit is granted.**

The AEC is expected to appeal the decision to the Supreme Court.

GAO raps NASA on Atlas-Vega project

The Government Accounting Office has criticized NASA for ever starting development of the Atlas-Vega rocket booster, cancelled last December. GAO claims the vehicle duplicated the Air Force's Atlas-Agena B. GAO charges that more effective planning and coordination between military and civilian space agencies would have prevented the go-ahead on Vega and saved the government the $16 million or more spent on the project.

Convair was prime contractor on Vega, a 3-stage satellite rocket booster designed to produce about 400,000 lb of thrust. First test launchings were planned for later this year. Lockheed is prime contractor on the Agena B, a 2-stage, 360,000-lb-thrust vehicle used to launch Discoverer, Midas, Samos, and later-version Tiros satellites.

Both the Vega and Agena projects were begun in the post-Sputnik rush to design superboosters that would place heavy payloads in deep space probes or in earth orbits. Vega was designed to carry heavier payloads than Agena. But the project's excessive cost and the rapid development of Agena prompted NASA to kill Vega.

Manned planes vs guided missiles

In the Congressional reshuffling of the defense budget, the lawmakers have become arbiters over the competing merits of manned planes and guided missiles in the air-defense field. The House cut $294 million from the Air Force's budget for the Boeing-Westinghouse-Marquardt Bomarc B antiaircraft missile, voting instead for $215 million to buy Convair F-106 fighter-interceptor planes. The Senate committee then restored the Bomarc funds and slapped down the aircraft addition.

A compromise decision is pending. Meanwhile, proponents of the rival weapon systems are lobbying manfully. The Bomarc–F-106 question represents the venerable Pentagon argument over how to divide limited funds between development of new hardware and procurement of weapons already operational.

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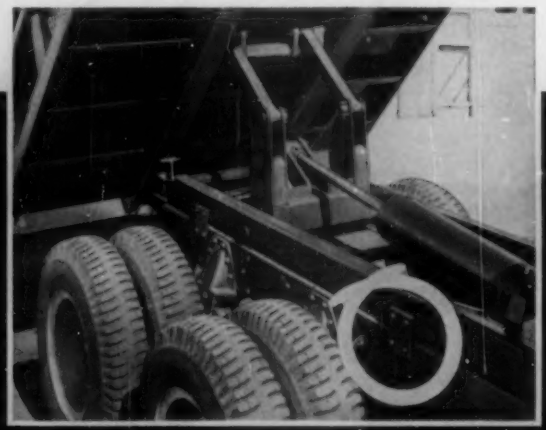
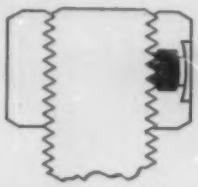


Dump body by Heil Company, Milwaukee, Wisconsin. Unit is anchored to the chassis by 16 Republic NYLOK Nuts.



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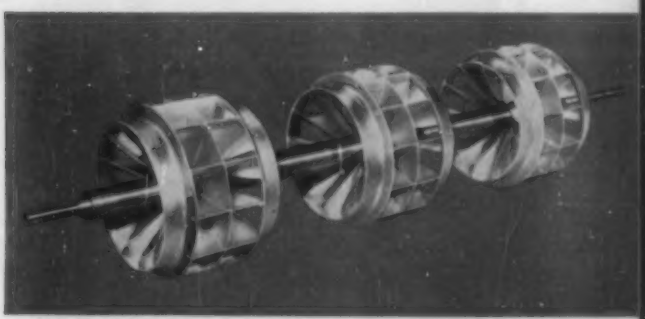
A nylon plug firmly staked into one of the faces of the cold forged hex nut forces a tight, metal to metal contact of opposite mating threads for vibration-proof lock.

POWER TAKE OFF COUNTER-SHAFTS cost Ford Tractor Division less to produce using Republic Die-Form Blanks, as compared with previous materials. Minimum machining is required, handling costs and scrap loss are reduced. Pictured are the blank and completed shaft. Clip and send the coupon for information on the savings potential of Republic Die-Form in your operations.

PAINT STAYS ON. Selection of steel for overhead doors on U.S. Post Office trucks involved two important factors: steel must meet rigid government paint adherence specifications, yet must be economically priced since the manufacturing contracts are on a competitive bid basis. Gerstenslager Co., Wooster, Ohio, chooses *Republic Electro Paintlok*® to meet these requirements. Send coupon for more Electro Paintlok information.



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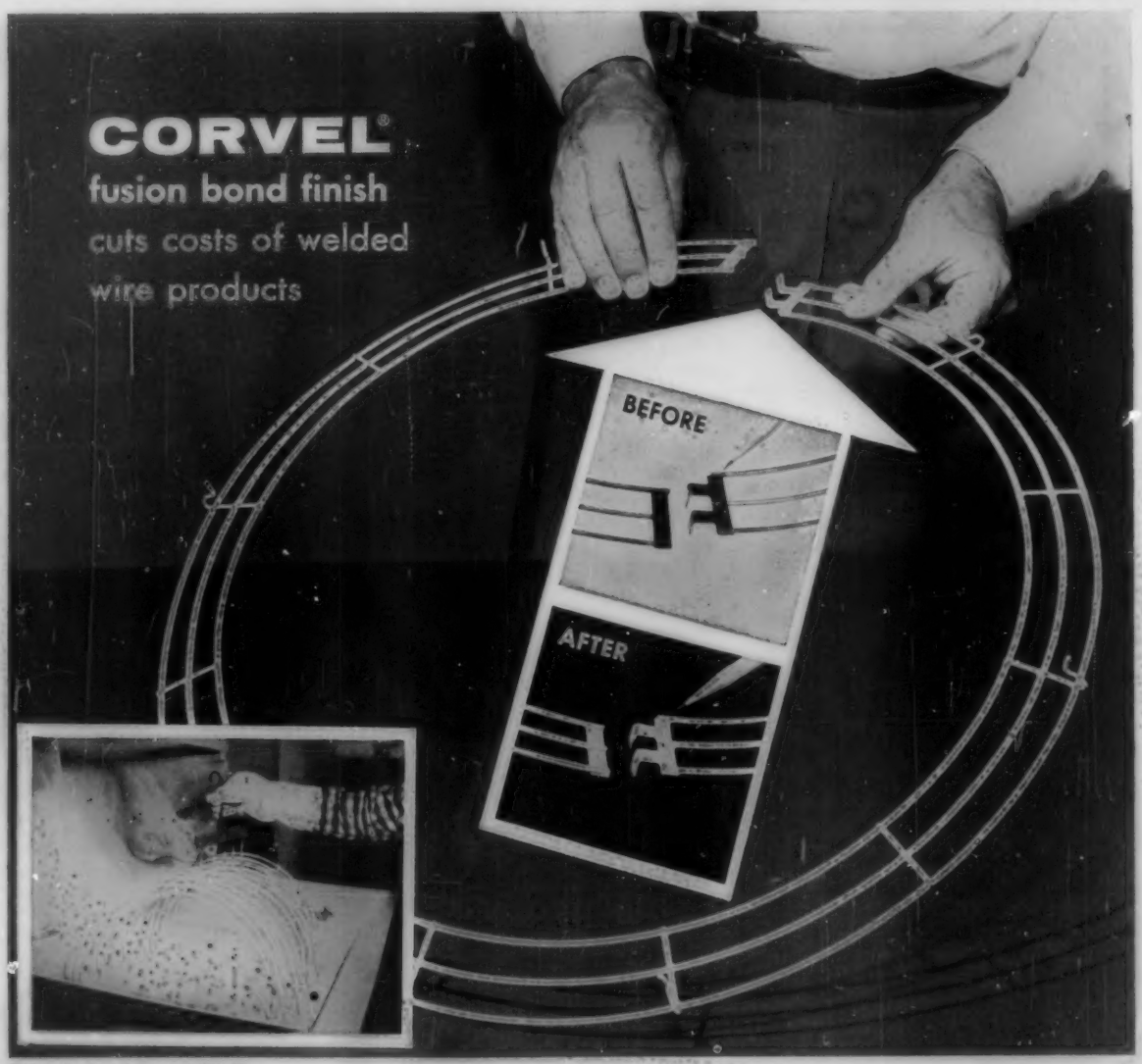

Photo courtesy Bauer Brothers, Springfield, Ohio

Before and after photos of this washer clothes guard dramatically demonstrate the savings possible with CORVEL fusion bond vinyl finishes on welded wire products.

Sharp edges and rough weld flash on the bare wire were completely covered in the WHIRLCLAD* Coating System†. Grinding and other deburring operations were eliminated.

Economical bright basic wire, excellent for CORVEL finishes, saved about ¼¢ per pound over premium priced, extra-clean, extra-bright wire necessary for plating processes.

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CORVEL finishes are specially processed dry powders for use in the WHIRLCLAD Coating System and are available in cellulosics, vinyls, epoxies, nylon, polyethylene and chlorinated polyethers.

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†The WHIRLCLAD Coating System includes basic procedures and apparatus developed and patented in Germany by Knapsack-Griesheim A. G. of Frankfurt, Germany. The WHIRLCLAD Coating System is protected by various apparatus and process patents in the United States and foreign countries, and numerous patent applications are pending. Exclusive patent and licensing rights in the United States and Canada are owned by Polymer Processes, Inc., a subsidiary of The Polymer Corporation.

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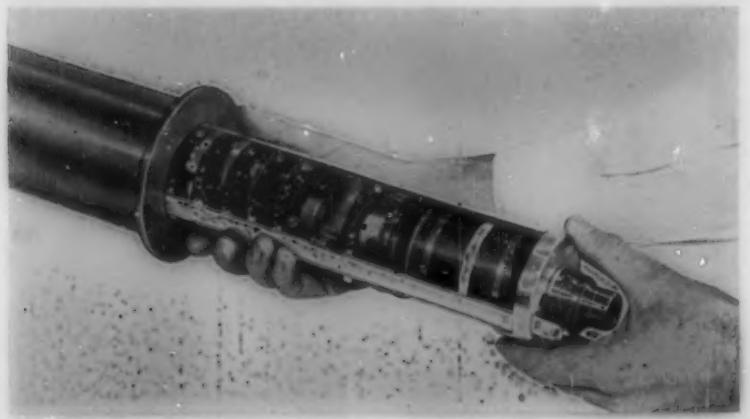


CYLINDRICAL TV CAMERA is transistorized; 3 in. dia and 14 in. long, it's housed in ½-in. steel casing capable of withstanding depth of 36,000 ft. A 2-in., conical Lucite window is sealed in front of the steel housing to protect the tube. Four such cameras are mounted on the tank—two view the ground at the rear and two monitor the manipulator arm from the front and rear. System can transmit the image of one camera through a central control unit at a rate of 15 scans per sec. Either low-resolution images, resulting in a 250-line picture, or high-resolution images, producing a 530-line picture, can be made.

Down to the Sea's Floor in a Tractor

WASHINGTON—A small underwater tractor has been developed for the Office of Naval Research to enable scientists to probe deep into the seas for long periods. The remote-controlled experimental vehicle has all the necessary trimmings—mechanical arm, closed-circuit TV and sonar gear.

Called the Remote Underwater Manipulator (RUM), it will let scientists reach deeper for samples and specimens, and assemble and install instruments on the ocean floor. It was developed by the Maine Physical Laboratory of the Scripps Institution of Oceanography, Univ of California, La Jolla.

RUM consists of the basic hull and truck assembly of an Ontos tank, on which has been mounted the long-jointed manipulator arm and hand. Underwater TV cameras send visual information back to the vehicle's operator on shore; specially designed sonar gear guides RUM's progress over the ocean bottom.

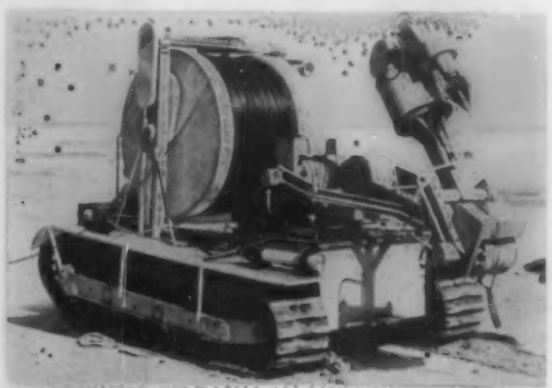
5 MILE RANGE, 20,000 FT DOWN

The tractor is linked to a mobile van on shore by a cable long enough to permit operation 5 miles from shore. Besides carrying the TV signal, this coaxial cable relays power that operates the vehicle, the camera and mercury-vapor lights. It also provides several remote-controlled telemetering channels.

RUM can be operated at depths of 20,000 ft, maintaining a speed of 3 mph when terrain of the sea bottom permits. It can maneuver and operate on grades of 60%, can climb a vertical obstacle 12 in. high.

The stainless steel arm is a sealed, oil-filled unit with a special reservoir to compensate for the difference in compressibility between oil and sea water. Designed by General Mills Inc, the electromechanical device simulates motions of the human arm, and its hydraulically actuated boom lets it reach out and operate at a maximum of 15 ft in any direction. Both boom

REMOTE CONTROL CONSOLE, housed in a mobile van on shore, is linked to RUM by a busy coaxial cable. It carries the power that operates the vehicle itself as well as its four TV cameras and their mercury-vapor lights. It brings back the TV signal with which the operator views the underwater scene and operates the mechanical arm.



UNDERWATER TRACTOR is equipped with manipulator arm (right), spool of coaxial cable, and mercury-vapor lights (note the pair installed just above the vehicle's track). Two main propulsion motors (standard GE 7½-hp series-wound 800-rpm units), coupled through standard truck transmission and differentials, independently drive RUM's two tracks. Hydraulic controls provide normal braking action, while a spring-actuated friction brake automatically operates in emergency.

and arm are operated by toggle switches from the control van.

Operation of the vehicle and its manipulating arm is guided by 4 TV cameras. Illumination for the cameras at pitch-black ocean depths is provided by mercury-vapor lights attached to the vehicle's rig. Each of the cylindrical cameras is housed in ½-in. steel casing capable of withstanding a depth of 36,000 ft. ■

Fattened Defense R&D Nears Final Juggling

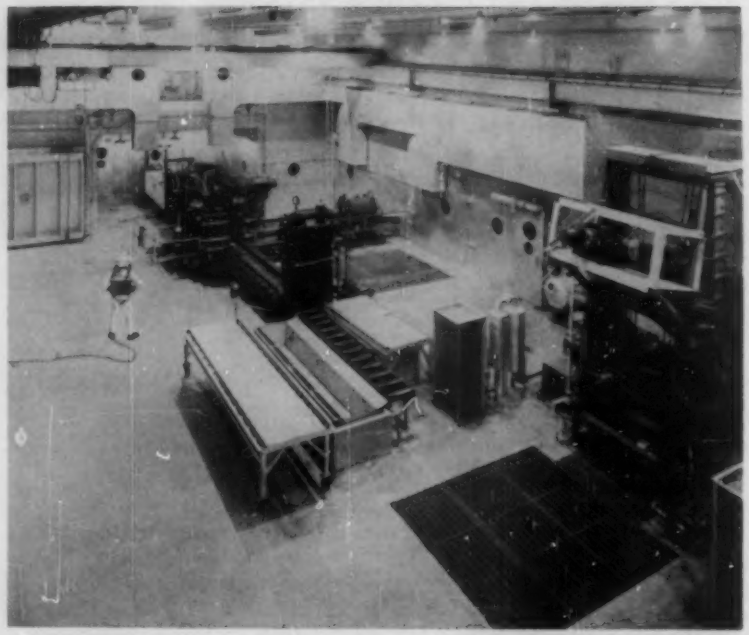
WASHINGTON—The Pentagon's R & D appropriation, industry's largest source of design-engineering awards, is going through the final stages of the Congressional wringer. As the situation stands now, Congress will boost the budget. But the increase will be nowhere near the massive sums Senate leaders were calling for right after collapse of the Summit talks in Paris last month.

The House has already jacked up the R & D budget $300 million over the Administration's request to a total $4.2 billion. The Senate Appropriations Committee approved a similar increase last week, but earmarked the extra funds to different projects.

Largest R & D increases voted by the Senate committee were for North American Aviation's B-70 (from $75 million to $360 million) and Lockheed's Samos reconnaisance satellite ($83.8 million extra). The committee rejected House-approved R & D increases for the Minuteman ICBM and antisubmarine warfare.

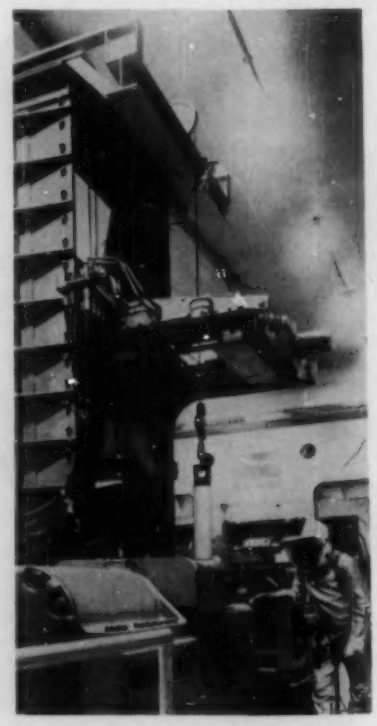
The B-70 budget boost, if accepted by the House (most likely) and the Administration (uncertain), would mean restoration of three major subsystem development projects for the Mach 3 bomber: IBM's inertial-type bombing-navigation system, Westinghouse's electronic countermeasure system, and Motorola's mission and traffic-control system.

The three projects were cancelled last year when the B-70 program was trimmed back from development of a weapon-system status to fabrication of one or two stripped-down prototype aircraft for flight testing. At the time, $60.8 million had been spent on the three subsystems—out of a total $550 million in the B-70 program. ■



INTERIOR VIEW—layout of equipment, and room for future expansion. Technician wears space-type suit with oxygen supply and cooling unit on his back. Trailing wire leads to remote-control stations outside enclosure, and power supply. Surrounding argon is kept above atmospheric pressure to prevent contaminating air from leaking in. Manual handling of material into facility and transferring betwen equipment requires personnel to enter the chamber.

Inert Fabrication Promises High-integrity Exotic Metals



BRIDGEVILLE, PENNA—By allowing hotter working temperatures, a new inert-atmosphere method offers the answer to the problem faced when processing refractory metals—their tendency to become contaminated.

As a result, molybdenum, columbium, tungsten, and their alloys will be processed here as high-integrity mill products by the Refractomet Div of Universal-Cyclops Steel Corp. Refractomet also conceived, designed and constructed the fabrication facility.

This is a welded steel enclosure 42

MOLYBDENUM INGOT being lowered into heating furnace located beneath the impactor. Ingot is heated to 4500 F (conventional is about 2300 F) and transferred into forging position in 2 sec, keeping heat loss to minimum. Remote-control impactor hits ingot on two sides with 15,000 ft-lb energy, normally produces 4-in. round-cornered square billets and 2x10-in. sheet bars. Mill is equipped with both flat and grooved rolls to produce bars to ½ in. OD and sheet to 15 in. wide, 96 in. long. Through pack rolling, sheet gages of 0.020 are obtainable.

ft wide, 97 ft long, 23 ft high, and filled with a protective argon atmosphere. In the building are an impactor, rolling mill and furnaces that will forge and roll the refractory metals at temperatures to 4500 F.

The company points out that these metals offer great promise for applications requiring high strength at ultra-high temperatures. But it adds that present methods of fabricating don't permit full utilization of the inherent properties of refractory metals; they should be hot-worked at temperatures double those possible in conventional mills. Molybdenum, for example, at normal working temperatures oxidizes catastrophically; the other metals are contaminated by elements in air. Inert argon gas permits high-temperature working and improved metal properties.

The impactor, rolling mill, and furnaces are designed to be fully automatic and are controlled from consoles outside the facility. Future plans call for conducting experiments on hot-machining and welding of the refractory metals, which will require personnel to work within the facility. ■

Missilemen Exchange Views on Safety Problems

RIVERSIDE, CALIF—An Air Force general has warned industry not to use the term reliability "to camouflage additional charges for functions which are an intrinsic part of effective industrial operation."

Speaking before the 45th Air Force-Aircraft Industry Conference on Missile Safety here, Major-Gen Ben I. Funk told 250 missile experts from the US and Britain that the Air Force was willing to pay for specific costs incurred to improve reliability; but it expects to see results.

The purpose of this conference, as keynoted by Brig-Gen Walter E. Arnold, flight and missile safety director of Norton Air Force Base, was "to examine the relatively new field of missile safety, to exchange ideas and methods on how to solve current safety problems and to forecast future problem areas requiring early preventive action." This was the second Air Force-industry parley to concentrate on missile safety problems.

As evidence of the Air Force's growing cost consciousness, Gen Funk noted that his service pioneered a program for interchange of component test data among all ballistic-missile and space contractors of the three services. These data, he said, should help accelerate attainment of higher reliability and reduce cost duplication.

The Air Force General also reported that weapon-system analyses have been performed to arrive at optimum distribution of funds between R & D, production, operation and maintenance costs. A general shift toward R & D to increase the effectiveness of over-all expenditures is now taking place, he said.

G. T. Wiley, vice-president and general manager of the Martin Co, Orlando, Fla told the group his company has found that "better than 80% of reliability of an end product is created by the engineer in his basic design. But given a reliable design, the problem of maintaining our reputation rests squarely on the shoulders of the man in the quality and manufacturing side of the business."

Martin's design goal, he said, "is always toward developing systems which have the minimum number of parts. We have found through experience that if we spend more time making these simple instead of sophisticated, our reliability goes up and the cost comes down. As a matter of fact, we can solve most of our problems by simplifying—by taking out the moving parts and putting in fixed structures. This, at any rate, is our goal. Admittedly, we can't always do this; but we try." ■

Elephant-like Fork Truck Has Adjustable "Tusks"

Designed especially for heavy work at steel and lumber yards, this "Ranger 700" general-purpose fork truck by Clark Equipment Co can lift 35 tons. Twelve ft high at the cab, it's 24 ft long (without forks), 11 ft wide; each of its four tires is 74 in. high. Its forks, weighing 1½ tons each, are moved together or apart hydraulically to fit different load widths. Lifting and tiering are accomplished through two 9½-in.-dia. lift cylinders and two 9½-in. tilt cylinders. Ranger can tier to heights of 12 ft and more, if necessary. Because its massive loads can obstruct driver's forward view, truck is equipped with two sets of operating controls; by swiveling in his bucket seat, driver can use the rear controls to drive in reverse. The truck is powered by a 6-cyl diesel, 425 cu-in. displacement; has a 4-speed transmission and torque converter. Max speed is 12 mph, price is $85,000.

Inertial Guidance Steers Atlas to Target Area

HEMPSTEAD, NY—US missilry took a long step forward last week when an Air Force Atlas soared some 5000 miles and fell within the prescribed target area. This particular missile was the first fully inertial-guided flight of an ICBM in the free world, an official of the company reported.

American Bosch Arma Corp, designer and builder of the guidance system, reports it generated all necessary steering signals and the test met all programed objectives. Among the advantages claimed is immunity to any known ground interference after

launching, to atmospheric disturbances or communications breakdown.

Inertial systems do not require extensive programing, thus a missile can be fired immediately after fueling. Checkout of the various systems is handled within minutes by semi-automatic equipment during fueling.

Arma engineers are now working on more-sophisticated, lighter-weight equipment for future missiles. These miniaturized versions will be applicable in space vehicles and short-range missiles, where extreme accuracy and reliability are prime requisites. ■

Technical Emporium: British Show Export Wares

NEW YORK—The British have just finished making a sizeable bid for a share of the US market. Ten million dollars worth—the best of their automobiles, radar, TV, telephone-exchange equipment (some of it all-electronic), jet engines, gas turbines and consumers goods—all this and more was spread over 200,000 sq ft of New York Coliseum's display space at the exhibit just concluded. It was sponsored by the Federation of British Industries, the Dollar Exports Council and the British-American Chamber of Commerce.

Among products shown was a recently unveiled multifuel engine developed by Rootes. This 2-stroke, 3-cyl, opposed-piston unit is said to work on jet fuels, kerosene-base fuels, gasoline and diesel fuels. An adjustment in fuel-pump setting is sufficient to switch from one fuel to another. The pistons drive a single crankshaft through rocker beams. The unit shown develops 105 bhp at 2400 rpm, has maximum torque of 270 lb-ft at 1200 rpm. Originally designed for trucks, the engine is now being produced for automobiles. Rootes also is working on a large 6-cyl model.

The Atomics Div of Pye Ltd demonstrated a 3-D television system developed especially for atomic facilities where the operator of mechanical arms must move objects that cannot be directly seen through a window. He must depend on a TV image, and to give such images depth, Pye has added an arrangement of prisms at the camera that split the light beam in two. The two images are displayed against prisms at the viewing end. The human mind fuses these images into a 3-D view. The camera can be controlled and focused by the operator outside the radiation area.

Pye has also developed a TV camera, 3 in. dia and 48 in. long, that can be slipped into a reactor core to scan for damage. A mirror which fits into an aperture at the bottom of the TV housing can be tilted up or down for vertical viewing. Entire camera can be turned to obtain 360° view. All focusing and positioning operations are controlled from equipment outside the reactor area.

The British also showed a rapid-processing photographic projector that detects a faint image on a radar screen, develops it and projects a considerably enlarged version against a 18-ft screen. The process takes 6 sec. First applied to air defense systems, the projector is now available for other commercial and industrial systems. It is marketed by Kelvin & Hughes of Annapolis, Md, a subsidiary of S Smith & Sons of England.

Ferranti, a leading British company in the electrical field, is showing a rapid-inspection machine developed to keep pace with today's high-speed output from machine tools. The machine consists of two slides at right angles to one another. A probe or microscope moves along one slide and the assembly moves along the other slide. Both slides are equipped with Ferranti diffraction-grating measurement systems. Measurements taken as the unit plays back and forth over the horizontal axis are displayed on a panel in ¾-in. high numbers. The unit is said to be accurate to ±0.001 in., will take pieces as large as 15 in. by 24 in. and 15¾ in. high. ■

This microwave tube, developed by Sperry Gyroscope Co, is said to boost output power of military radar 5000 times for more precise tracking of missiles at longer ranges than formerly possible. A 100-amp electron beam in the tube's midsection generates some 3 million watts of radar power. Pointed white cone at top is a sapphire-like ceramic which passes the tube's intense output power to the radar's antenna while sealing output pipe against tube's ultrahigh vacuum. The tube's short wavelength, half that in earlier superpower tracking systems, provides sharper beams for pinpointing small missiles.

End of "Planned Obsolesence" Viewed as Improvement

NEW YORK—An official of a leading home-appliance manufacturer feels that the industry's current trend toward eliminating annual model changes will produce more innovations, not fewer.

B. A. Chapman of American Motors' Kelvinator Div says removing artificial deadlines will free engineers to work on such major projects as thermoelectric cooling, electronic heating and ultrasonic waste disposal.

In support of his views, Chapman points out that under Kelvinator's "constant basic improvement" policy, new ideas are applied to products and marketed as they are developed; for example, some 32 new ideas have been added to one washer in a year.

Asked if American Motors will apply this same approach to its automobile division, AMC president George Romney replied:

"We have already done this to a certain extent. Two of our lines (Rambler American and Metropolitan) have had no changes based on planned obsolescence (styling); they have only been changed to incorporate engineering improvements. ■

Transistorized Computer Cuts Space-Problem Time

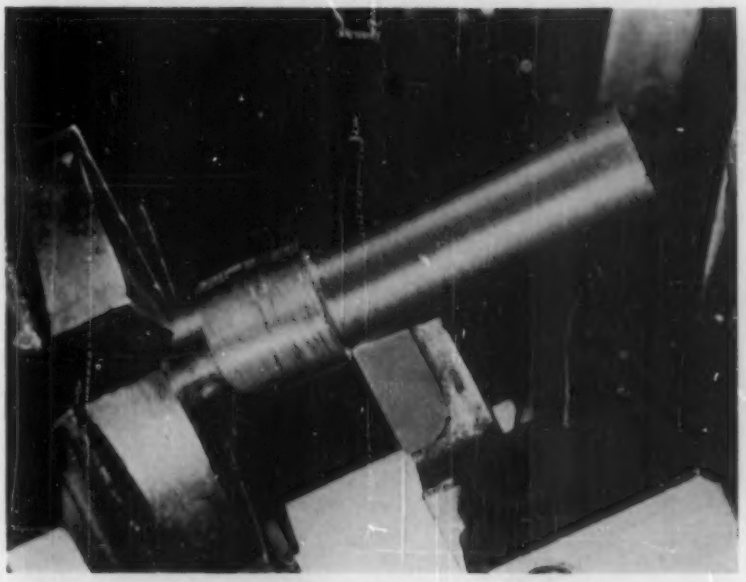
HUNTSVILLE, ALA—"The trend in computers used to be to faster and bigger machines. Today we seem to have changed direction. Now they're faster, smaller," said an IBM engineer.

IBM's fully transistorized 7090 computer was put into action here this month to help solve space flight computation problems for NASA's new Marshall Space Flight Center (formerly Army's Redstone). The new machine is both faster and smaller than anything even nearly as powerful. In a demonstration problem, the 7090 computed a space ship's trajectory starting from a position 120 miles above the earth, swinging out across the earth-moon axis, around the moon, and then back to earth in the familiar figure-8 pattern. The trip will take just under 10 days. The computer produced over 60 sets of position, speed and altitude data for the ballistics experts in just under 3 minutes.

The new computer can add or subtract six times faster than the 709 (the vacuum-tube counterpart of the 7090) and seven and a half times faster than the 704. The reason? It's got over 50,000 transistors plus a new core storage (see *PE—June 13, cover*) with a 2.18-microsecond access time.

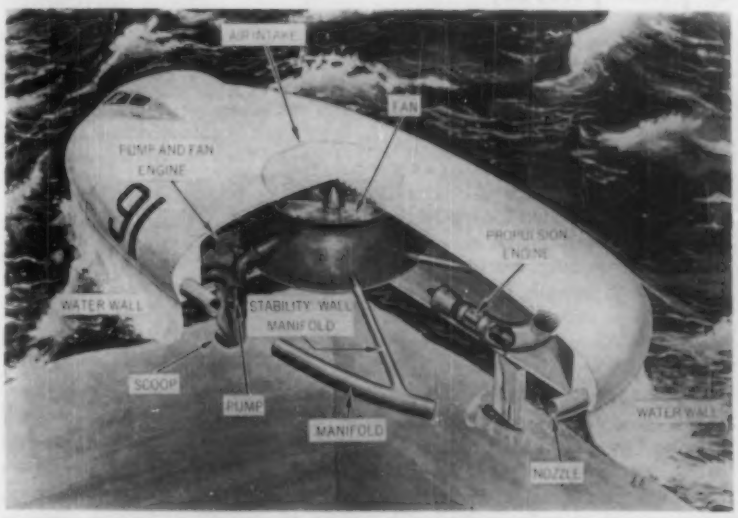
These high speeds forced IBM into the second important development embodied in this machine. It is called the SPOOK system (Supervisory Program Over Other Kinds) which guides and monitors, just as a human operator would, the sequence of control signals necessary to finish up one problem and start another. In this way there is no pause—no machine downtime—while the answers to one problem are being taken from the machine and the next problem is set in. The SPOOK is just another program—but it takes over responsibilities at a higher level than ever before given to the machine. ■

Machining Easier When Refractory Metal Is Single Crystal



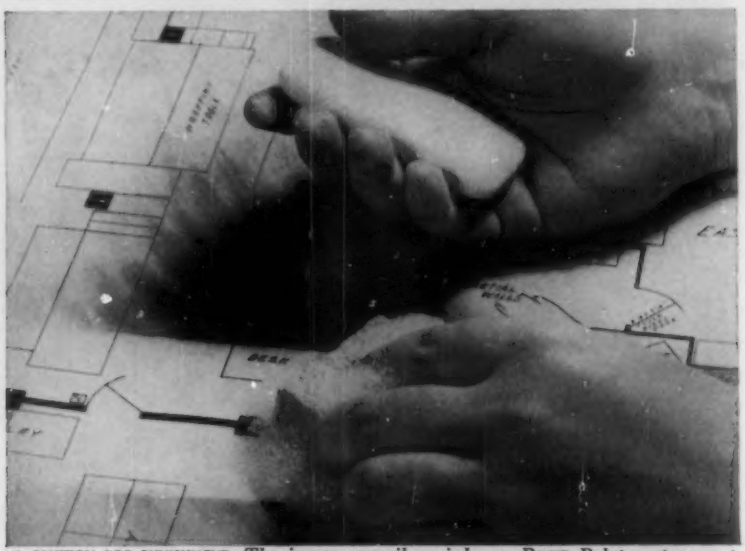
Boule of a large single crystal of tungsten is being turned at room temperature. Other refractory materials can be machined at significantly lower temperatures as a result of the development of large crystals of these metals by Linde Co, Div of Union Carbide Corp. Crystals are produced as cylinders in diameters of ¼ in. to 1 in. and lengths to over 12 in. The arc-fusion crystal-growing process is similar to the Verneuli flame-fusion process except that a wider range of temperatures and atmospheres are obtained with electric arcs as opposed to combustion flames. Linde reports that single crystals are available in production quantities in cylinder form or as fabricated shapes, such as rods and disks.

Boat Speeds on Air—with Water for a Curtain



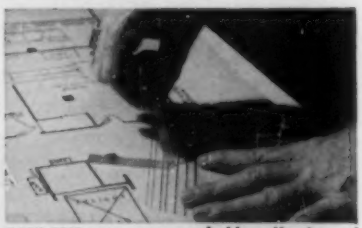
Again that air-lift principle—here with a boat instead of a ground-traveling vehicle. The air-cushion vehicle cruises 2 feet above water, with speed said faster than attainable by conventional craft of its power and size. The boat's skegs (vertical stabilizers), and its twin screw-propellers run by two 80-hp engines, are submerged during flight. Water plus skegs provides curtain-like wall that traps air beneath the vehicle. Source of air bearing is a fan, driven by a third 80-hp engine. The craft, which was demonstrated recently on the Potomac Lagoon, Washington, DC, is 21 ft long, 11 ft wide, weighs 2 tons when empty. It was developed by Hughes Tool Co, and Navy's Bureau of Ships.

DRAFTING TRENDS



A GLUTTON FOR PUNISHMENT. *The image, pencil or ink, on* POST *Polytex stays put. Won't rub, flake or peel off accidentally, yet can be erased. Duralar pencil lines bond to the surface readily. Soiled originals can be washed with water and detergent!*

New POST-perfected Polytex takes pen or pencil perfectly



TAPE TEST *proves remarkable adhesion of inked lines to the surface of* POST *126 Drafting Film, lines which do not feather out or spread.*

You already know that drafting films offer the advantages of tremendous durability and dimensional stability. Now, thanks to an exclusive, precision process, POST offers a drafting film with superlative drafting characteristics. The surface of POST 126 Polytex is unmatched for ink receptivity, has a coating that stands up, erasure after erasure. Ink lines won't pull off when cellophane tape is applied firmly over them and then suddenly yanked off. Transparency is excellent.

If you prefer pencil, use a POST Duralar lead for permanence. Plastic-based Duralar lines actually bond themselves to the Polytex surface. Drawings won't easily smudge or smear . . . can even be washed with soap and water.

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Enjoy the flexibility and long life of a drafting film with an ideal drafting surface. Try new 126 Polytex Drafting Film.

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READER TO EDITOR

From Drafting to Design

To the Editor:

One of our students, Donald Thompson, was interested in a letter to the editor, written by H. C. Spencer in your September 28, 1959 issue because Mr. Spencer stated that, "The department (Illinois Institute of Technology) is the only one in the country giving BS degrees in Technical Drawing . . ." From 1950 to 1956 Arizona State University offered a BS degree in Industrial and Architectural Drafting. Actually, the students specialized in either Industrial or Architectural Drafting, not both. The word "Industrial" was changed to "Technical" so that Industrial Drafting would not be confused with Industrial Design, which is offered by the College of Liberal Arts. The word "drafting" was changed to "design," because a student needs to qualify for a higher position than drafting if he has a college degree. Therefore, since 1958, students receive a BS degree in Technical Design. Essentially, the students learn the fundamentals of drafting, and lay a foundation in mathematics and science during the first two years. The last two years the students broaden their concepts and apply what they have learned the first two years to mechanical design.

—LUCILE B KAUFMAN, PE
Arizona State Univ
Tempe, Ariz

Stop Glorifying the Engineer

To the Editor:

Recently I quit my job as a senior design draftsman because some engineers —not all, but the majority—would override the objections of the draftsman. Then I had a job in which I was told I had the authority (or as industry puts it, the responsibility) of doing the engineering, design or layout work. Well, I lasted the week out and quit, because I'm not that good; I don't have the education or the experience in those 3 fields. I have 2 years of college and 30 years on the board, but I can't take the place of 3 men in 3 different fields; I know it because I'm either too practical or too honest.

The articles I read about engineers wanting to be placed in the same category as a doctor or a lawyer makes me ask why. A doctor or a lawyer's success is based on his ability to diagnose and be correct; the average person will soon give up the doctor or lawyer if they have to call in colleagues to get the right answer. Yet in the case of a motor, there is a mechanical engineer and an electrical engineer involved, plus the advice of hardware manufacturers.

When an engineering-college student gets a degree or diploma, he or she is an engineer but—what kind? A well engineered product has to have good technical help and good practical help. The draftsman should be able to put those ideas on paper so that theory becomes practical;

and then you also must consider metallurgy, tool design, quality control, the shop, etc. So why do we glorify the word "engineer"?

—Edward Jaekle
Lodi, NJ

Idiotproofing

To the Editor:

In the article, "Manual of Reliability," May 16, p 65, you stated that you would welcome comments. My comment is in reference to the interpretation placed on the results of our work and of other work concerned with missile damage from human factors.

Unfortunately, there appears to be a general tendency, which is reflected in this article, to take a look at the percentage of failures initiated by humans and to come to what I believe is a simple-minded and erroneous conclusion that we must make equipment "idiotproof." No one has as yet done any research to determine how many failures are prevented through the unique capabilities of man who is constantly called upon to overcome bad design. We do not consider a component to be at fault if someone uses it improperly in design or in operation. This is why we have been careful to use the term human-initiated malfunction rather than human error. Many human-initiated malfunctions are beyond the control of those operating the systems.

To take this discussion one step further, there has been some serious discussion of the necessity for sending a man into space in order to improve the reliability of the space systems. The "idiotproofing" that is most needed is the prevention of the "idiotic" use of man below or above his capabilities or without regard to what is the nature of his capabilities.

—Albert Shapero
Head, Systems Analysis Group
Stanford Research Institute

COMING EVENTS

JUNE

27-July 1 . . . . American Society for Testing Materials, 63rd Annual Meeting, Chalfonte-Haddon Hall Hotel, Atlantic City, NJ

AUGUST

1-3 . . . . Institute of Radio Engineers, 4th Global Communications Symposium, Statler-Hilton Hotel, Washington, DC

29-31 . . . . American Institute of Mining, Metallurgical and Petroleum Engineers, Conference on Metallurgy of Elemental and Compound Semiconductors, Statler Hotel, Boston

28-Sept 1 . . . . American Society of Mechanical Engineers, International Heat Transfer Conference, University of Colorado, Boulder, Colo

Another new Westinghouse AIR CIRCUITRY Component

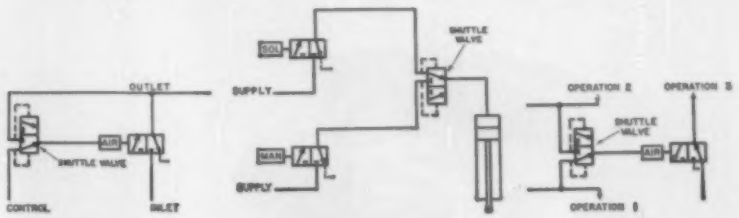
SHUTTLE VALVE

The Westinghouse Shuttle Valve automatically selects and directs the flow of air from one or the other of two controlling devices to a common outlet. It serves to connect two independent lines to a common line without destroying the segregation. A few of its uses are shown below.

Simple—Lightweight—Sensitive It contains only **one** moving part—an easily replaceable rubber diaphragm. Two body segments, a gasket and four screws complete the assembly. It has no springs. Nothing can bind or stick. Its compact size presents no installation problem.

Weighing only **6 ounces,** it can easily be supported by piping alone. Mounting feet are included, however, for installation with vibration or long pipe runs. It is so sensitive that it will seal off the opposite inlet line with less than 1 psi pressure differential.

TYPICAL APPLICATIONS



LOCK-UP
Insures an operation is held constant once initiated. Outlet line must be vented by another means to unlock the system. ("Memory" Circuit)

TWO-STATION CONTROL
Either of two controlling devices may operate the cylinders. Inoperative controlling device is sealed from the line. ("Or" circuit)

INTERLOCK
Prevents operation #3 when operation #1 or #2 is in process. ("Not" circuit)

AIR CIRCUITRY means trouble-free automation

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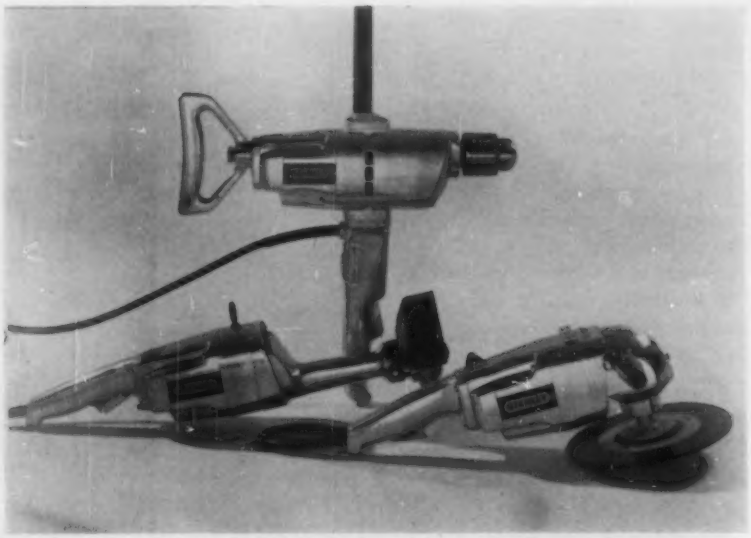
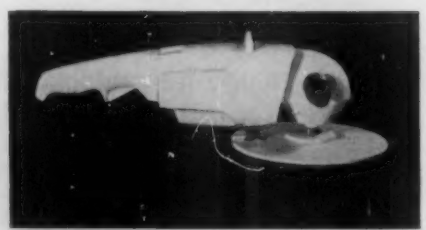
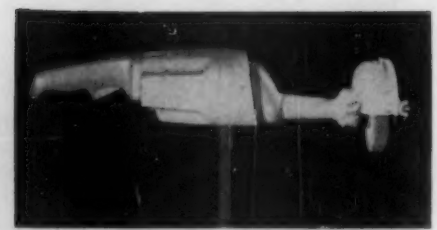


■ Hand-held industrial power tools such as these drills, grinders and polishers, by the Stanley Electric Tool Div, Stanley Works, are merchandised through mill supply outlets, rather than the usual retail outlets that handle home workshop tools. Hence, the emphasis on rugged durability in appearance. Yet a "family" look in such a line of products is still important. For one thing it enhances the cost-cutting possibility of employing common parts as much as possible throughout the line—and not just for exterior housings and components either, but for some of the interior mechanisms as well.

So that housing sections could be cross-checked for appearance, feel, and accurate dimensioning over the inte-





Industrial polisher (two photos at left), grinder (two photos at right) and drill (opposite page) are shown with their respective plasticene models. Note interchangeability of housing sections common to more than one tool.

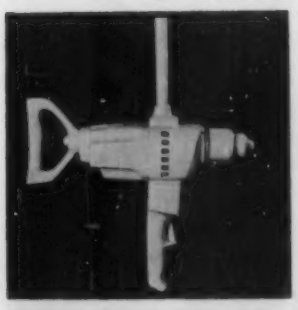
rior components, a single armature (framework on which plasticene modeling is done) was set up upon which models were developed in sections (motor, gear, spindle housings, handles, chucks, etc.). These were doweled and removable. Their exterior forms and dimensions were determined by doing the modeling right over blocks that represented the interior mechanisms, supplied to the industrial designer by the product engineer. Actual grinding wheels, disks and other such working parts were also used in this stage of the design job.

As a result, a motor housing was developed that is common to all 15 tools in this line (see sketch on this page, lower right corner—those parts numbered alike are common to more than one tool). The cowling at front of the grinder's gear housing permits air exhaust and also reduces visual mass. Although air exhaust from the drill is peripheral (note slots), front of its gear housing is shaped to retain cowl feeling.

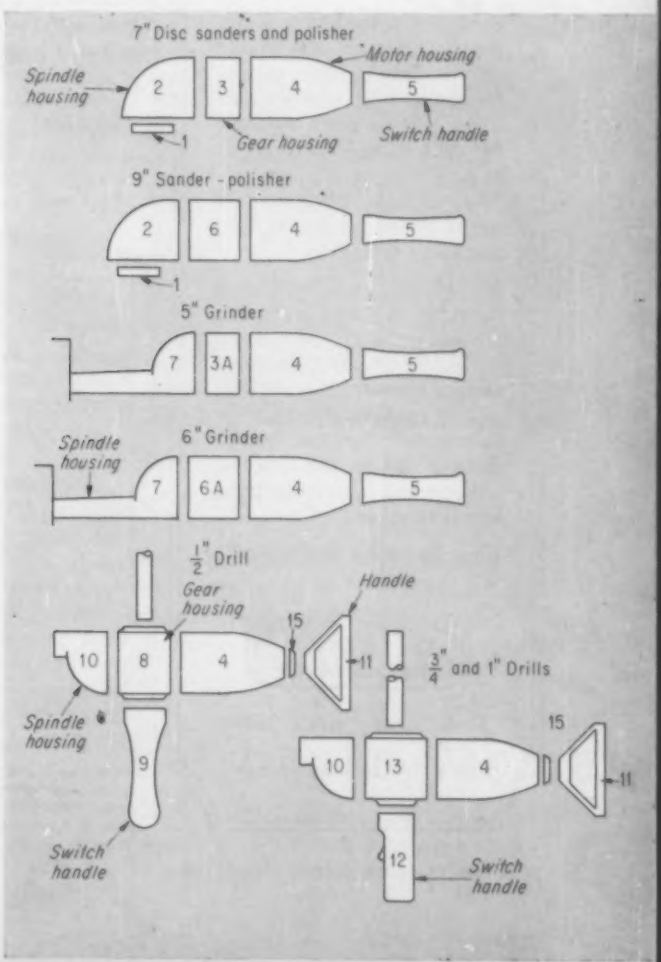
Handle shapes also underline family appearance. Note that although operating position of switch handle on grinder is horizontal and that on drill vertical, the only real difference between them is size. This means that they also help to carry out family resemblance, while the other types of handles ("D" handle in the case of the drill, spindle housing handle of grinder and polisher) suggest principal use of tool.

Aluminum diecastings were used wherever housing sections were common to enough of the line to provide suitable volume. For the rest, aluminum sand, permanent mold and shell mold castings were employed. This could have imposed a finishing problem, but was avoided by Stanley's developing a finishing process that gave similar surfaces to all cast parts.

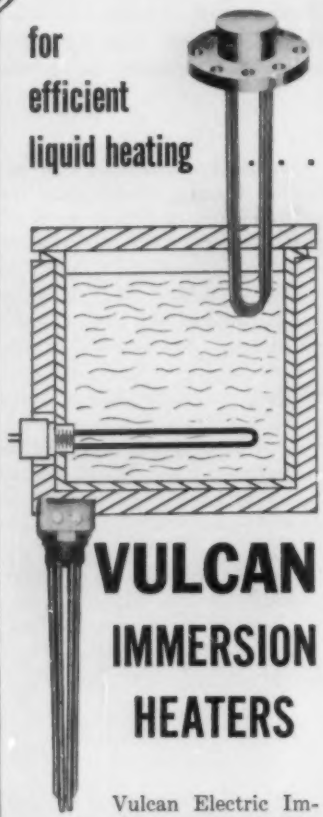
Industrial design of these tools was by consultant Laird Covey, Monroe, Conn. The development staff also included, from Stanley Electric Tool, James H. Godfrey, director of product engineering; Richard H. Russell, industrial designer; Kestutis Damijonaitis, product engineer; William J. Conlon, electrical engineer.■



Housing sections and components common to more than one tool are numbered alike in sketch at right. Note that same motor housing is used throughout.



for efficient liquid heating . . .



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Heaters are available with flange or threaded bushings; bayonet type, side or bottom outlet; copper, steel, stainless, or alloy sheath; single or three phase; readily adaptable to thermostatic control within close tolerances; full range of wattage and voltage ratings; pressures up to 3500 psi.

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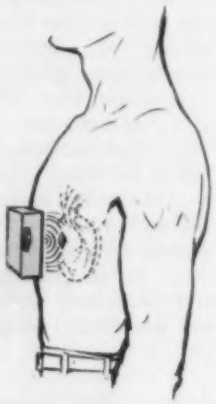
The following problems have been encountered by the Armed Forces. To submit a solution—or for additional information—write: National Inventors Council, US Department of Commerce, Washington 25, DC.



. . . a more reliable way of linking the human heart to an external pulse-generator. This device stimulates an ailing heart so that it will continue beating in regular rhythm. Now the pulses are generated in a small transistorized oscillator carried in the patient's pocket and fed to a probe in the heart muscle by a length of fine, flexible wire. But heartbeats constantly bend the wire and it eventually breaks. The most obvious solution is to develop a wire that will stand the fatigue of continuous flexing, but a better way is to eliminate the wire completely. Perhaps a small pickup could be implanted in the heart muscles to deliver pulses via magnetic induction.

. . . a greaseless ballbearing that will operate continuously for a year or longer at temperatures up to 1200 F. At present the bearing is needed for motors and generators mounted in space vehicles. These require bearings in the 200 series of sizes up to 206 and larger. (A 206 bearing carries a shaft about 1 in. dia.) Speeds are constant and range from 10,000 to 100,000 rpm for different applications. Bearings must be able to handle radial loads to 75 lb and axial loads to 25 lb, and withstand shock loads to 50 g for 11 millisec. After installation in the motor or generator, the assembled unit must withstand storage for a year or longer at −80 to 160 F and 100% relative humidity.

Also needed is an antifriction bearing, for automotive applications, with corrosion resistance of stainless steel but load-bearing ability of bearing steels. This would reduce the need for frequent field maintenance. Bearings for these applications range in size from miniature instrument bearings to large turret bearings for tanks of about 100 in. dia. Speed of the small bearings runs up to 10,000 rpm while larger bearings turn as slowly as 5 rpm.

. . . an extremely small accelerometer with dimensions on the order of $\frac{1}{8}$ x $\frac{1}{8}$ x 0.01 in. Must be capable of measuring accelerations from 10 to 1000 g. Resonant frequency must be at least 100,000 cps and response at lower frequencies should be uniform to permit accurate measurement of random noise vibration. Should allow cementing to any surface, and be unaffected by magnetic fields or adjacent magnetic materials.

. . . an altimeter for missiles to measure height over target by principles other than pressure sensing, electromagnetic radiation, inertial sensors, time-from-launch, or other standard altitude-measuring techniques. Must measure altitudes up to 5000 feet with accuracy of ±10%. The complete device should not weigh more than 10 lb. One possible approach: a device to sense change in gravitational attraction and relate it to altitude.

Have you a problem, based on known scientific principles, which seems to have an answer somewhere within the limits of present technology? To inspire inventors along worthwhile paths, PRODUCT ENGINEERING invites you to trade such problems with fellow readers who have a fresh viewpoint or more time to experiment. We pay $10 for each one accepted.

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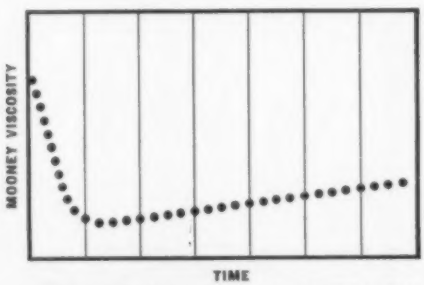
Its Mooney Scorch Rating is ideal for the fluorinated rubber processor because it makes possible fast, more economical cures with fewer defects, less scrap, fewer rejected parts. Material can be reprocessed with greater safety.

A SIGNIFICANT BREAKTHROUGH in elastomer processing has been made possible by 3M research through development of its new FLUOREL 2141 Elastomer.

This remarkable new product has a Mooney Scorch Rating outstanding among fluorinated elastomers. The range permits the rubber processor to achieve fast, more economical cures with fewer defects, less scrap and fewer rejected parts. The inherent safety of FLUOREL Elastomer 2141 allows repeated reprocessing to produce high quality parts that meet military specifications or other critical end uses.



MOONEY SCORCH CURVE for FLUOREL 2141 Brand Elastomer.

At the same time, the outstanding physical qualities of the elastomer are retained. They include: non-combustibility, excellent resistance to corrosive chemicals, fuels, solvents and ozone, minimum compression set, rated for continuous service at 400° F., and the ability to tolerate 600° F. temperatures for reduced periods under certain service conditions.

If you use or work with elastomeric materials, it will pay you to examine the remarkable features of this new product. Examine, too, your present rubber products with an eye toward increasing their life and quality through use of FLUOREL 2141 Elastomer. For complete data, write today on your company letterhead to: 3M Chemical Division, Dept. KAS-60, St. Paul 6, Minnesota.

FLUOREL 2141 "O" ring, bottom. Note freedom from defects because of the improved scorch characteristics of FLUOREL Elastomer "O" ring as opposed to elastomer at top of photograph.

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MINNESOTA MINING AND MANUFACTURING COMPANY

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Bruning Electric Eraser. Minutes add up to hours saved over manual erasing. Bruning's original hollow-shaft eraser features 7" erasers for extra economy and tracing protection, provides convenient, finger-tip switch. Trouble-free sealed bearings.

Bruning Drafting Aids. They add up to hundreds of man-hours saved! Complete line includes everything from adjustable triangle for faster, accurate drawing of angles to special purpose templates for quicker, neater execution of symbols and shapes.

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NEW IDEAS IN COPPER ALLOY ROD AND WIRE

Interesting things happen when you add a spot of zirconium or chromium to copper—four high-conductivity coppers that boost production, cut cost of machining—even plain old free-cutting brass rod is going fancy.

There's a quiet revolution going on in copper metallurgy. Research and development teams are expanding the useful knowledge of copper and copper alloys in an effort to define the properties most suitable for specific engineering applications.

STABILITY at elevated temperature, combined with good electrical conductivity, is probably a combination most sought after by design engineers and by our industry's research teams. Two alloys are now commercially available, and the alloy systems are unique. Chromium copper and zirconium copper are heat-treatable alloys with good stability of mechanical properties up to temperatures in the order of 600 F.

CHROMIUM copper in the fully heat-treated condition following a solution anneal will exhibit properties combining a tensile strength of about 75,000 psi with conductivity of approximately 80% IACS. Zirconium copper has good stability characteristics at elevated temperatures and conductivity of 90 to 95% IACS; the strength properties developed by heat treating are, however, somewhat lower than chromium copper.

SEVERAL other heat-treatable copper alloys with intermediate properties are gaining recognition in the connector and electronics fields. These alloys fall into a conductivity range of 35 to 65% IACS, with tensile strengths 90,000 to 100,000 psi. The most popular alloy systems are the copper-nickel-phosphorus and copper-nickel-silicon series with modifications for free machining or other specific requirements. These alloys have a solution annealing temperature about 100 to 200 C lower than the chromium and zirconium coppers.

THE WIDESPREAD use of panel or harness construction for linking segments of electrical control devices has made the requirement for free-cutting coppers mandatory. Screw machine shops are fabricating these connector components of various designs by the millions. Currently the most popular free-cutting coppers are leaded copper with conductivity of about 98% IACS, and tellurium and sulfur coppers at about 95% IACS. Some of these free-cutting coppers have residual oxygen and can become brittle or gassed under the usual conditions contributing to this phenomenon. All, however, can be obtained with a combination of deoxidizers or oxygen-free copper. In the case of the deoxidized variety, some slight sacrifice in conductivity will be noticed. Ordinary usage very seldom requires conductivity in excess of 90% IACS – and this presents no problem for these coppers.

ALL of these coppers can be cold worked without too much trouble. They can be supplied in a suitable wire temper for cold heading and secondary operations designed around the basic alloy system. Up to now there has not been too much interest in these alloys for wire forming or heading operations. Close dimensional tolerances may be the reason for the reluctance of the heading people to get into the electrical connector business. Alloys are available with the ductility and mechanical properties necessary for this type of forming. It would appear that some of the products could be made more economically by cold-heading or wire-forming operations.

RECENT TRENDS have also affected the old brass and copper reliables. There can't be any product more prosaic than free-cutting brass rod; it is the cheapest of such commodities and at one time was the easiest to process—all one had to do was to extrude, draw to finish dimensions, and ship. In many cases this practice won't work today. Deep drilling, roll threading, knurling, staking, slotting, etc., have complicated the picture, but the latest efforts of the screw machine builders have laid this ghost to rest. We now hear of beta-free rod for close tolerances on deep-drilling applications. Similar grain structures, but not necessarily the same temper, are required for roll threading, knurling and staking or whenever extra ductility is needed. Along with the consideration of grain structure, it has been necessary to take advantage of the broad chemical composition range for free-cutting brass. Most suppliers divide the standard range into two parts, utilizing the lower copper range for the larger sizes that will normally be machined on the heavier, faster screw machines where chip breaking and clearing the tools are the most important considerations. This might be considered the rough, breakdown type of stock.

FOR the smaller diameters, specialization has been the watchword. Depending on specific needs, you can now obtain free-cutting brass rod with all-alpha, fine-grained structure or an alpha-beta fine-grained extruded structure, or possibly a combination of both. For certain applications you might need a coarse-grained, all-alpha structure. Lead dispersion and lead content are other variables that can and will be controlled to meet fabricating or end-use requirements.

IN the cold-heading industry, advantage is being taken of the wider selection of copper and copper alloys that is available today. The nickel silvers, phosphor bronzes, and silicon bronzes combine good ductility and high strength with excellent corrosion resistance. The whole range of common brasses has specific applications and can be tailored to various heading operations.

The research and development hopper is full of interesting new ideas and projects at The American Brass Company. It could be that we're working on something which would help solve one of your problems. Even though we don't have the complete answer, perhaps we could both reach a solution faster by pooling our efforts. Call your American Brass representative and talk it over with him or write: Manager, Market Planning, The American Brass Company, Waterbury 20, Conn. 6050B

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PRODUCT ENGINEERING HORIZONS

June 27, 1960

TOO MANY TOOLS

Some months ago, at the conclusion of a lecture to sophomore industrial design students at North Carolina State College, I handed out a problem: to design a new container for paint. The idea was to develop something for the small-lot buyer that would reseal airtight (thus preserving remainders), that could be completely emptied, that could be opened without tools, that provided a brush-wiping flat surface.

At the next class session, each student posted and described his solution to the jury—his classmates, the instructors and me. There were obvious mistakes; there were cases of faulty calculation and faulty reasoning, but there was a great deal of ingenuity and originality too. Some solutions were downright clever and quite practical. And all had been done by the student on his own in spare time out of two days.

This was no isolated instance; it's a regular occurrence in Professor Baer's teaching approach. He believes the student should be pushed into something a little beyond his knowledge, be challenged by problems somewhat like those he'll encounter after graduation.

I mention this policy because it is so sharply in contrast to the current approach of many engineering educators. Since World War II, and more so since Sputnik I, emphasis has been shifting toward science, math and physics and away from engineering. No longer does the student design an engine or a punch press—"he hasn't sufficient experience or knowledge." The practical design problems come out of the curriculum except for some for which data are previously spoon-fed. The argument is that the student needs more fundamentals, and that the engineering will take care of itself afterwards.

This just isn't so. No graduate's stock moves up if he falls on his face on his first assignment. The argument is reminiscent of Disney's dwarfs, who explained Dopey's failure to talk as not dumbness but just because "he never tried." That's what "momism" is—protecting the young at home and abroad, never letting them learn by doing, by falling on their faces while the ground is still fairly close. And "momism" isn't practiced exclusively by mothers.

R. T. Langeman

How INDEX TABLE *DESIGN* affects INITIAL PRICE and TOTAL COST

Study these drawings to see how the design of an index table affects total costs of an installation. Some tables may be priced lower than others initially, but the additional charges for auxiliary items to adapt them to production requirements, added to maintenance and downtime costs, can make a drastic difference in **the total price.**

The Ferguson Intermittor, indexed by a roller gear drive which operates a minimum of 8,000 hours at speeds up to 2,000 indexes a minute without maintenance, needs no auxiliary locking. It is designed for high speed operation and incorporates rigid integral supports for tooling to eliminate expensive segmental components. The Intermittor dial is supported by tapered roller thrust bearings to withstand heavy loads with little friction. A stationary center tooling support is held rigidly at its top by anti-friction radial bearings and at the bottom by a flanged base bolted to the housing. Hollow center of the support may be used for passage of coolants, fluids, air or vertical shafts to transmit motion to the work surface.

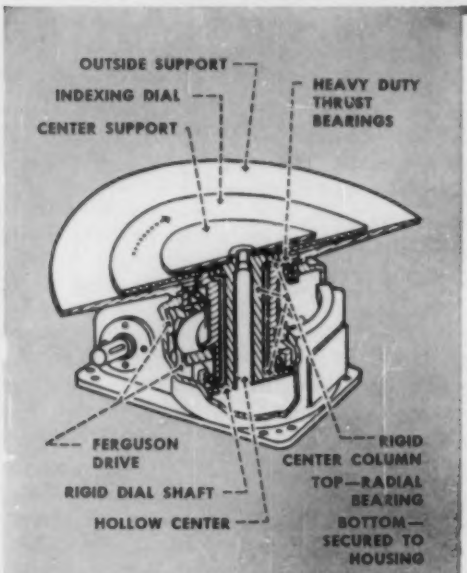

FIG. 1—FERGUSON INTERMITTOR

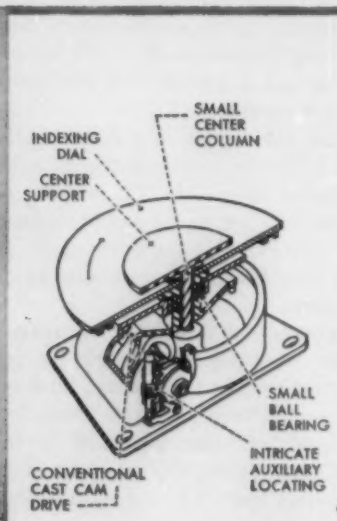

FIG. 2—BARREL CAM TYPE

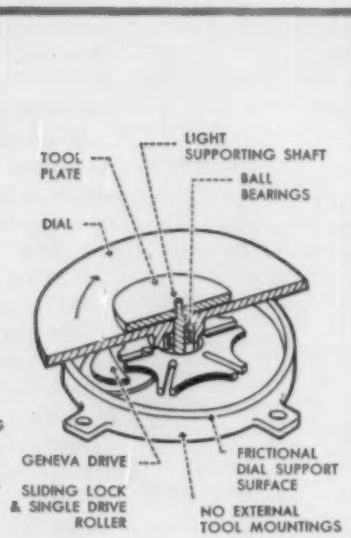

FIG. 3—GENEVA DRIVE TYPE

Figures 2 and 3 show typical barrel cam and geneva drive index tables. Their indexing mechanisms limit operating speeds, therefore other components may be "designed down." Shafts and bearings are lighter; frictional support surfaces might be employed instead of thrust bearings and an auxiliary locking or locating device is a costly necessity for even modest accuracy requirements. Tool mounting methods are often provided at additional expense and sometimes even ignored. Difficulties of installation and frequent maintenance downtime can increase total cost drastically.

• SEND FOR CATALOG

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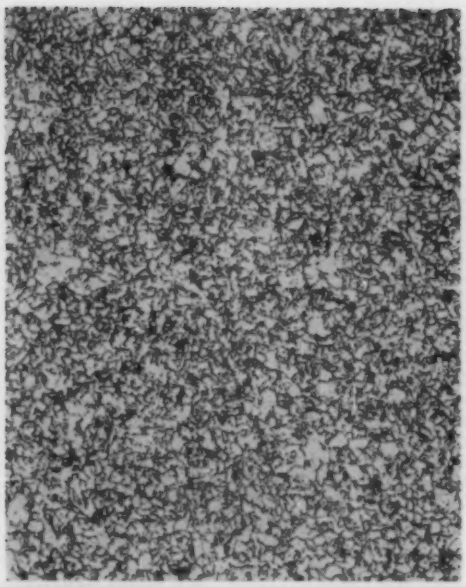
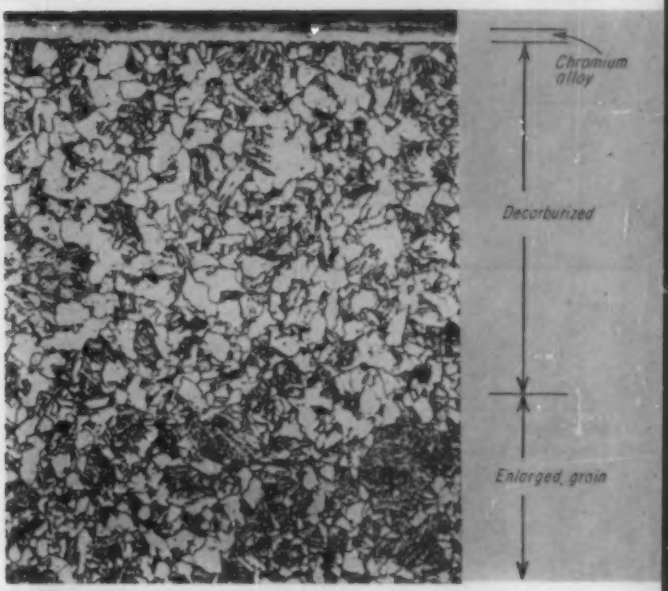


BEFORE



AFTER

Enlarged grain and decarburized zone in chromized steel at right explains why this protective treatment alters the base metal's mechanical properties. New data from Great Britain tells how . . .

ALUMINIZED AND CHROMIZED COATINGS CHANGE

STEEL PROPERTIES

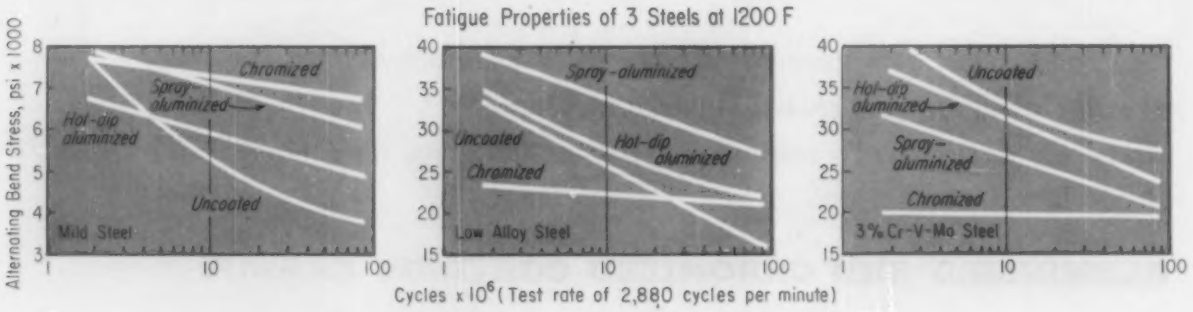
E A BRANDES
Fulmer Research Institute
Stoke Poges, England

Either chromizing or aluminizing steel will protect it against rusting, high-temperature oxidation and scaling. This protection comes from converting a thin surface layer of steel to an alloy. Because the processes require heating above the recrystallization temperature, some grain growth takes place and is attended by some loss of short-time tensile strength. With chromizing, some decarburization also occurs and this decreases the short-time strength still more. But for long-time service at elevated temperature, both coatings add oxidation resistance that may fully compensate for the reduction in strength. Main difference is that with aluminizing—spraying and hot-dipping—no decarburization occurs and short-time strength is affected less.

THE COATING METHODS

Chromizing is more effective than aluminizing in preventing oxidation of steel. For the chromium diffusion coating, parts are packed in a steel box with ferrochromium powder, an ammonium halide and inert material; the

Material	Composition, %	Condition	At Room Temperature			At 1200 F		
			0.2% yield, psi × 1000	U.T.S., psi × 1000	Elong., %	0.2% yield, psi × 1000	U.T.S., psi × 1000	Elong., %
Mild Steel	C 0.05 Mn 0.3	Bare	44.8	51.1	35	7.6	10.8	79
		Chromized	14.1	37.2	47	4.5	10.5	62
		Hot-dip aluminized	39.4	47.9	34	7.6	11.6	71
		Spray-aluminized	29.6	40.3	22	6.5	10.1	48
Low-alloy Steel	C 0.09 Mn 0.5 Cr 0.39 V 0.53 Mo 0.26	Bare	55.5	77.1	20	29.3	40.1	31
		Chromized	30.5	49.7	34	16.8	27.8	25
		Hot-dip aluminized	58.0	83.8	15	29.3	39.9	27
		Spray-aluminized	46.6	75.7	18	28.5	39.4	29
3%Cr-Ni-V Low-alloy Steel	C 0.23 Mn 0.43 Cr 2.80 Ni 0.70 V 0.79 Mo 0.50 W 0.52	Bare	139.6	153.2	11	62.9	76.6	19
		Chromized	58.2	90.0	15	30.0	38.8	18
		Hot-dip aluminized	133.1	149.0	12	52.4	70.8	15
		Spray-aluminized	101.9	144.7	12	41.0	50.6	23



box is heated for 10 hr at 1830 F, then cooled in air. Three factors are at work here: As chromium diffuses in, higher chromium content converts the case from austenite to ferrite; at the high processing temperatures, carbon actively combines with chromium to form a stable carbide; carbon diffuses faster through ferrite than through austenite.

A TYPICAL CYCLE HAS 4 STAGES:

1–Heating; no chromium is yet deposited.

2–As it reaches temperature, Cr starts to diffuse into the steel; body of steel is austenitic at this temperature so carbon diffusion is slow.

3–Holding at temperature; case changes to high chromium ferrite, and then chromium carbides form and deplete surface of carbon. Because carbon diffuses rapidly through the now ferritic layer, decarburization of the substrate starts.

4–Cooling; carbon still rapidly diffuses and heavy decarburization proceeds at a decreasing rate as temperature falls. Decarburization of the outer layers in turn leads to grain coarsening here.

These changes have more effect on material that is less than $\frac{1}{8}$ in. thick.

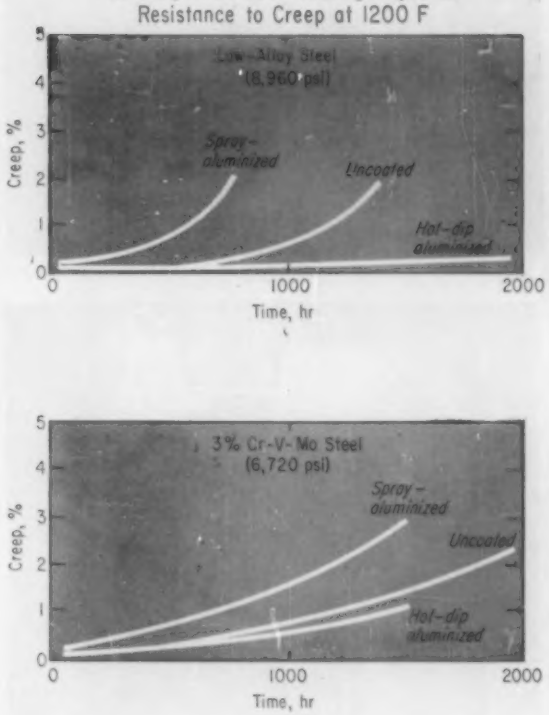
Hot-dip aluminizing gives a protective layer when steel is dipped into a bath of molten aluminum. In this process, steel is degreased and pickled, then given a copper flash by dipping it into a solution of acid copper sulfate. Next, it is quickly dried and dipped into molten aluminum for 3 minutes at 1360 F. The surface of the steel reacts with the aluminum to form an intermetallic compound about 0.006 in. thick. Dipping also leaves a film of aluminum on the surface.

Spray aluminizing puts the coating of aluminum onto a cleaned steel surface. The steel is shot-blasted and then sprayed with about 0.09 oz of aluminum per square foot. (Thickness is not a reliable measure because of the rough surface and high percentage of oxides in the coating.) The sprayed aluminum is then diffused into the steel by heating the parts for 15 minutes at 1475 F.

Mechanical Properties

Creep at 1200 F, %		Fatigue Strength at 1200 F, psi × 1000		
(1120-psi stress)		(2,880 cycles per min.)		
50 hr	4000 hr	1.7 million cycles	17 million cycles	86 million cycles
0.3	5.45	7.7	4.7	3.8
0.04	1.38	7.8	7.2	6.8
0.28	2.8	6.7	5.6	4.9
0.13	2.0	7.9	6.8	6.2
(6720-psi stress)				
50 hr	300 hr			
0.02	0.03	33.2	23.5	15.9
0.23	8.40	23.7	22.2	21.1
0.04	0.05	34.9	25.3	21.3
0.05	0.11	39.2	32.0	27.1
0.08	0.22	41.7	30.2	27.1
0.01	0.04	19.9	19.7	19.5
0.06	0.22	36.1	30.0	23.3
0.16	0.48	31.4	24.9	20.4

Hot-dip Aluminum Coating Improves Resistance to Creep at 1200 F



HOW COATING AFFECTS PROPERTIES

Chromizing generally reduces the ultimate tensile strength and therefore the creep resistance and fatigue properties. However, at long-time service at elevated temperatures oxidation resistance is improved.

Room-temperature strength of the mild steel is markedly reduced by chromizing, but there is only a small reduction in the already low strength at 1200 F. Chromizing increases creep resistance by preventing oxidation; fatigue strength is similarly improved.

For alloy steels (compositions given in the table) chromizing reduces both hot and cold tensile properties. Creep properties are seriously reduced in the low-alloy steel and improved in the 3% Cr-Ni-V alloy. At 1200 F, oxidation controls the creep of the 3% Cr-Ni-V steel and protection given by chromizing outweighs reduction in strength from the structural changes that occur in the coating treatment.

Chromizing causes a large loss of fatigue strength in short-time tests. For long times, the oxidation resistance of the coating becomes more important. For example, at 500 hr (86.4 million cycles) the chromized low alloy steel is better in fatigue than the uncoated. For still longer times, the advantage of chromizing becomes more marked.

Aluminizing treatments are not as effective as chromizing in preventing oxidation, but do not require heating to as high a temperature. Therefore grain growth is less. Furthermore, aluminizing processes do not cause decarburization.

Room-temperature strength of mild steel is slightly reduced by aluminizing (probably from grain growth). For the two alloy steels shown in the table, strength reduction is fairly small although hot strength of 3% Cr-Ni-V steel is lowered more than that of the low-alloy steel.

Hot-dip aluminizing improves creep resistance, while spray aluminizing reduces it. The effect varies with the alloy, as shown in the creep curves.

In fatigue, aluminizing treatments improve properties of mild steel and low-alloy steel at long service times by improving oxidation resistance. For the already fairly oxidation-resistant 3% Cr-Ni-V steel, there is a lowering of fatigue strength for times up to 1000 hr. Beyond 1000 hr, the effect of aluminizing is not known.

EDITOR'S NOTE: For more details on these and other processes to gain protection against elevated-temperature oxidation, see these articles:

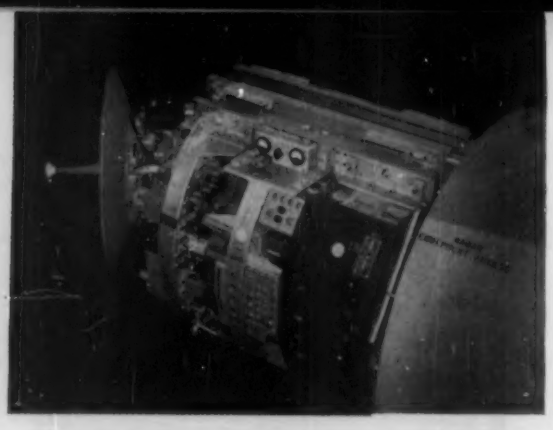
Which Coating at High Temperature, Jan 20 '58, p 61—Guideposts to the types of protective coatings best for corrosion resistance, erosion resistance, compatibility with base metal.

Hot-dipped Aluminum Coatings, Oct 28 '57, p 57—Aluminum hot-dipping lets you substitute less costly materials, lowers fabricating costs.

Chromizing for Resistance to Corrosion and Wear, Nov '56, p 180—How gaseous diffusion of chromium produces either ductile or hard surfaces on steel parts. Shows influence of base metal on the characteristics of the case and typical applications.

New Developments in Sprayed Metal Coatings, June '56, p 194—Advanced design of spray guns permits economical spraying of metal alloys and ceramic materials. Compares properties of alloys sprayed by the new equipment.

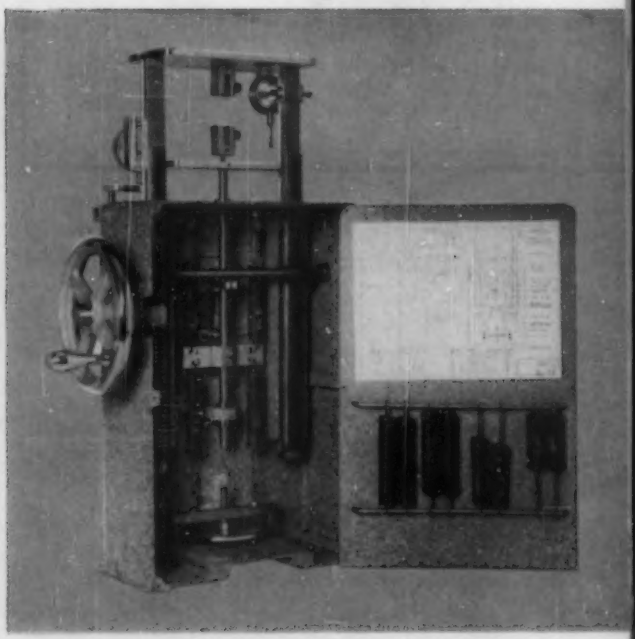
your guide to

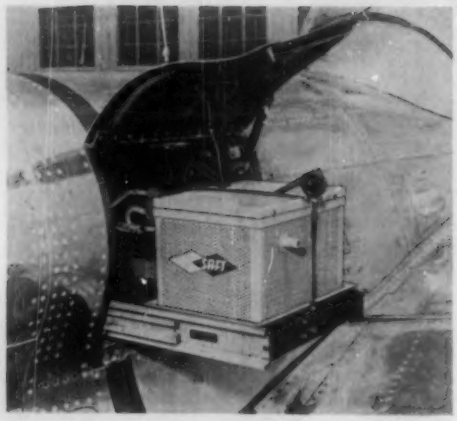


A

B

C





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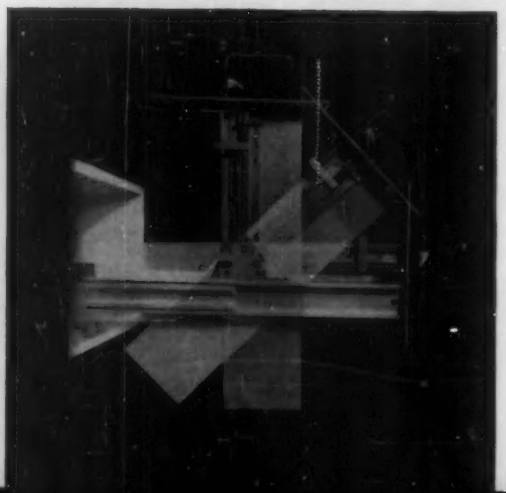


Slide Applications

A RADAR EQUIPMENT in nose of Douglas F4D Jet is mounted on telescoping ballbearing slides and pulled out for quick servicing. Slides are made of 2024T4 aluminum and support a load of 513 lb.

B DISPLAY UNIT is rolled out from back of automobile on a pair of long slides.

C SPRING TESTER uses two-channel slides as low-friction machine ways to support vertically moving rack.

D BATTERY IN TEMCO TRAINER is mounted on slides for quick removal.

E ELECTRONIC EQUIPMENT can be pulled out of a unit and pivoted to permit easy servicing.

BALLBEARING SLIDES

Many unusual applications are now possible with the wide diversity of slides available. Here's a rundown on basic types, load capacities and best mounting methods.

DR KURT KLOPSTOCK
Director of market research
Grant Pulley and Hardware Corp
West Nyack, NY

High-capacity ballbearing slides are an outgrowth of the common drawer slide–and the resemblance is not hard to see. Basic components of a slide are the telescoping track sections (either two or three in number) which move freely on a series of steel balls or on rollers. The balls are usually retained by means of a spacer whose function is similar to that of a separator in ballbearings.

Slides can be designed to function (1) as machine ways to provide low-friction, linear sliding members capable of bearing high loads, or (2) as telescoping members to support loaded chassis or drawers in a cantilevered position. The slides are often equipped with devices for locking the slide in various positions, and with pivoting mechanisms that allow the supported unit to be pivoted. These features have made possible a wide diversity of applications:

In electronic equipment–to permit a chassis, crowded with components, to be pulled out of its unit, supported in a cantilevered position, locked in place, and pivoted to a 45° or 90° position for speedy maintenance or testing.

In machine tools–to act as low-friction machine ways for positioning tools and equipment.

In aircraft–to provide means for quick access to auxiliary units, such as radar equipment and batteries.

In automatic transfer machinery–to reduce friction of reciprocating levers for transferring moving crates.

In display racks–to move heavy, bulky products effortlessly.

Other applications include slides for pulling out submarine sleeping berths, and for sliding back the windows of a helicopter.

Types of Slides

Ballbearing slides are fabricated from aluminum or steel shapes–with aluminum usually preferred for weight considerations. The slides employ either two or three track sections–the three-section slides permit a chassis or drawer to be pulled out completely beyond its retaining enclosure.

Most of the Grant Pulley slides have self-retained ball spacers composed of two metal strips with pronged holes to hold the steel balls in position at desired spacing and to prevent loss of balls if slides are taken apart.

Track sections are cut to length and put through a straightening process. The ball races of the tracks are then broached to obtain the close tolerances required to prevent play in the final assembly. This results in slides with little side play–a desirable feature for most applications, but one that often calls for shimming when assembling the slides in cabinets. Recently, slides have been developed with flat-groove center tracks to permit a deliberate slight side-play that avoids shimming.

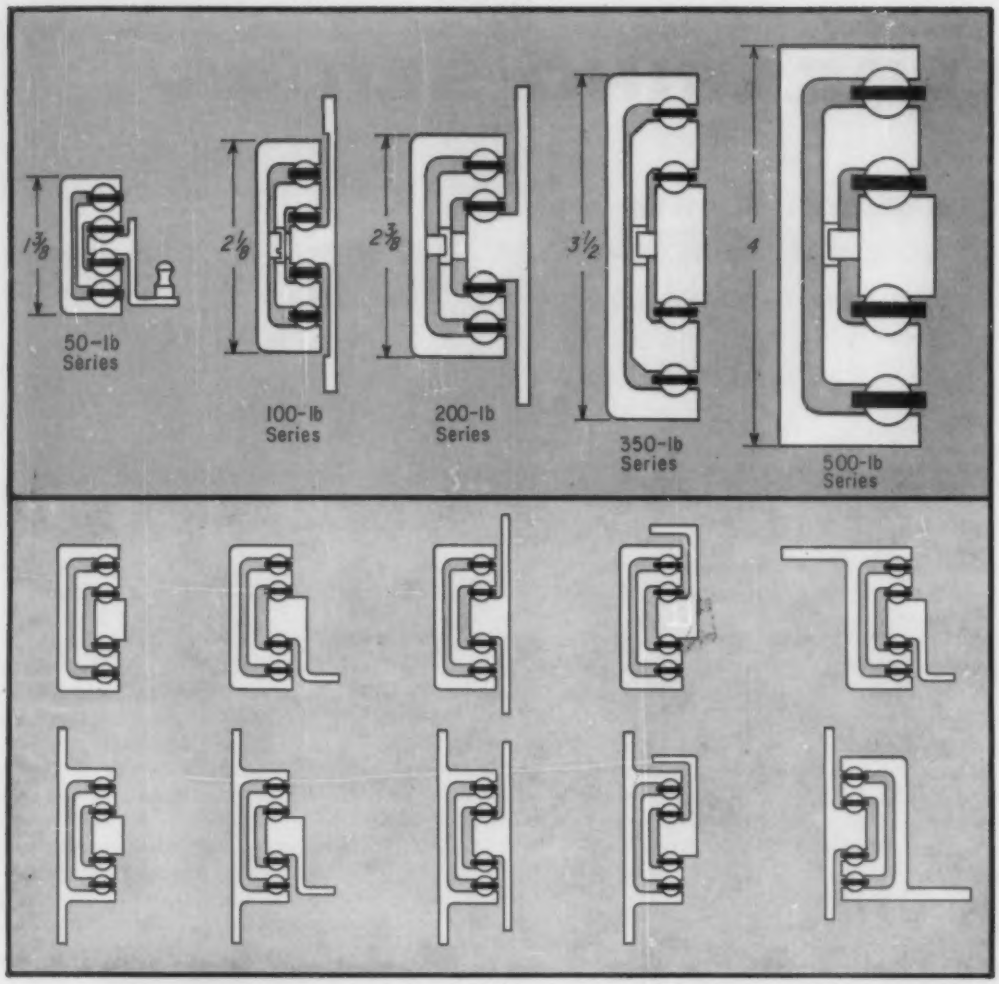
Sections are available in a variety of shapes and can be assembled in various combinations (see chart on next page). This allows wide latitude in mounting the equipment. The sections fall into several series based on the over-all size of the cross-section and the nominal (or base) load capacity. Slides are always load-rated as pairs.

Standard Sizes

Dimensions have been standardized by Grant Pulley in one-inch increments of length ranging from 12 in. to 40 in. for various series of slides. Specifying a particular length automatically calls for a particular slide travel and set of mounting holes. The slide travel (distance a slide will telescope out) has been standardized at slide length less 1 in. But the travel can be easily changed to give a 17-in. travel instead of 15 in. for a 16-in. slide by changing the ball spacer. For the slide down (p 37), travel T, length L and ball-spacer length S are related by the equation: $T = 2\ (L - B - 1\frac{1}{2})$.

The pattern, spacing and size of mounting holes have

FIVE BASIC SERIES ▼



AND THEIR VARIATIONS ▲

also been standardized. However, variations in these patterns are often necessary because of the many ways that the slides can be mounted in a cabinet or retaining unit. Therefore, slides are sometimes supplied with special mounting holes.

Load Capacity

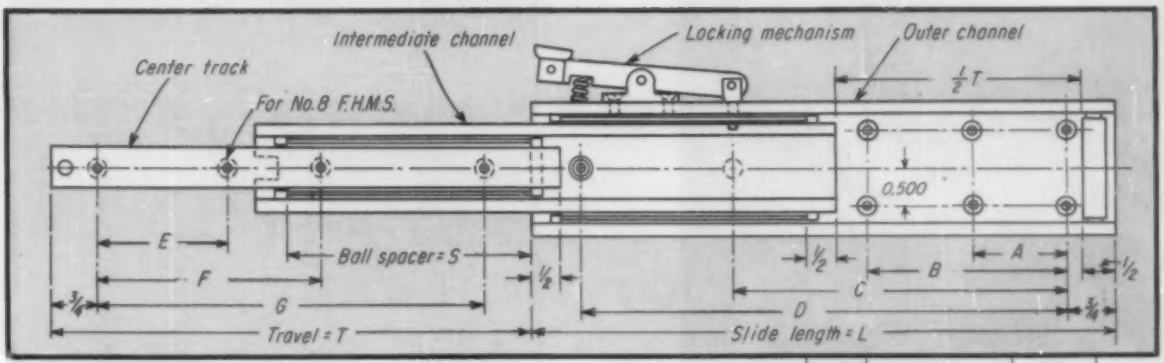
Series of slides are available with base-load capacities rated at 50, 100, 150, 200, 350 and 500 lb per pair. The base loads are for slides with an 18-in. length and 17-in. travel for all but the lightweight 50-lb series, which are rated at 14-in. length and 13-in. travel.

These loads are based on tests in which pairs of slides were extended and closed for 10,000 cycles while supporting a chassis with a load in its center. Deflection and wear of the ball grooves were measured and a 50% safety factor was then applied to determine the base load.

The load curves, next page, help determine load capacity for slides of other length or travel. For example, for a 200-lb series slides, 18 in. long with a 20-in. travel, the length factor is 1. The travel factor (desired length minus desired travel) is −2. The load factor is 0.78, and the load capacity is 200x0.78 = 156 lb per pair (instead of a base-load capacity of 200 lb per pair).

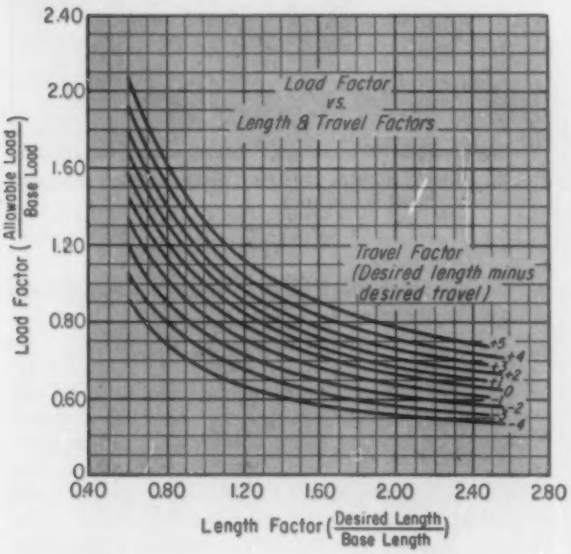
Deflection is the main factor limiting the load that can be placed on a slide. With excessive deflection, the internal parts will rub on the ball grooves, scrape off chips, and make the slide inoperative. However, rather high deflections can occur without harming the slide and without producing a set of more than a few hundredths of an

Standardized dimensions and mounting holes

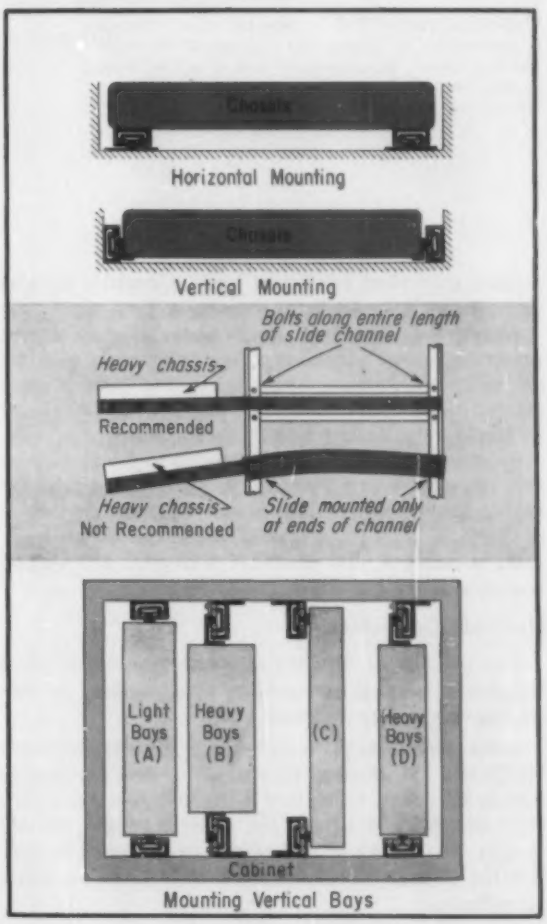


L	T	S	A	B	C	D	E	F	G
16	15	8	3	6	10	14	5	9	14
17	16	8	3	6	10	15	5	10	15
18	17	8	3	6	11	16	5	11	16

Variations in load capacity



Methods of mounting slides

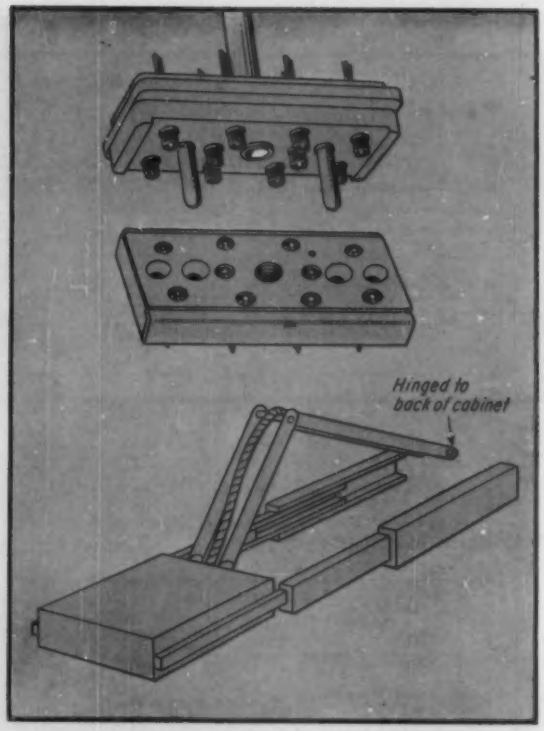


inch. For example, the 500-lb series slides are rated at a base length of 18 in. with 17-in. travel. If the slides are made 24 in. long with a 23-in. travel, their recommended load capacity (from the curves) drops to 0.78 x 500 = 390 lb. However, if a 500-lb load is placed in the slides they will deflect only ½ in. when in the extended position. This load does not make the slides inoperative; in fact, the load can be doubled and the slides can still be operated—but life will be reduced in more than linear proportion.

Mounting Methods

Slides mounted in a horizontal position for underneath support of a chassis (sketch, at right) have a load capacity approximately half of vertically (side-) mounted slides. This is why the underneath type of mounting is recom-

TROUBLE-SHOOTING a tape transport chassis is facilitated by tilting the equipment on ball-bearing slides. Equipment is part of a PACE 231R analog computing system manufactured by Electronic Associates Inc.



ELECTRICAL CONNECTIONS: (top) in-line connectors; (bottom) extra-long cables.

mended only when insufficient space is available for side mounting.

Bolting along the entire length of the channel reduces deflection in the extended positions. Ferrule pins are provided with L-shape center tracks that permit quick removal of the chassis. Tolerance problems can be reduced by employing a floating type of anchor unit.

Electronic chassis are often mounted in a vertical position for ease of maintenance. In the same sketch: the load is light enough (A) to permit horizontal mounting of slides; (B) is for heavy bays; (C) is for cases where headroom is cramped; (D) combines horizontal and vertical slide mounting.

Electrical Connections

The problem of handling electrical connections when the chassis is rolled out on slides can be solved by employing one of these methods:

In-line connectors to "break" contact, such as Methode's "Reli-con," Amphenol's "Blue Ribbon," or Continental's rectangular power connectors (illustrated above at right). Once the chassis is aligned, the slides will track perfectly so that the connectors will mate properly upon closing. But the electrical connection is broken when the slides are pulled out.

Extra-long cables, pivot plates or other means to take up the slack upon closing. This method permits the chassis components to remain energized while the slide remains in an extended position.

Special Slides

"Thin" slides are a recent development for aircraft and navy craft applications where space on sides of chassis must be kept to a minimum. These slides can be made as thin as $\frac{1}{8}$ in. but with a resulting loss in side-sway rigidity. A full complement of balls is employed between telescoping sections to eliminate the ball spacer. The slides are available with locking and pivoting mechanisms.

Record-player slides are inexpensive two-section assemblies made of rolled channels and used primarily for permitting the pullout of a record player. The player shelf is easily removed from the slides by pulling out a pin at the rear of the center track. The ball spacer has a silencer spring to cut down troublesome vibration when the record player is extended.

EDITOR'S NOTE—For other types of slides or sliding devices see:

Round Bar Slides for Machines, Dec '52, p 162. Analyzes round bars with split housings, bronze bushings, hardened steel bushings and tapered bushings.

Nine Types of Ball Slides for Linear Motion, Sep '50, p 128. Includes V-grooves, ball cartridges, sleeve bearings with steel balls, and bushings with recirculating ball systems.

PRODUCT ENGINEERING

SPECIAL REPORT

THE SIGNIFICANCE OF Wk^2 AND HOW TO CALCULATE IT

When the load on a motor requires frequent starting and stopping or reversal, size of motor may be dictated by the power needed for acceleration—which depends on (1) moments of inertia of the moving parts referred to the motor shift, (2) the speed that must be attained, and (3) the time allowed for bringing the load up to speed

JOHN W HARPER, *Equipment Industries Engineering, General Electric Co*

if this looks familiar . . .

It is. We first published this article by Mr Harper in Oct, 1934. It produced an immediate and continuing response, as measured by requests for copies from readers. We had expected high initial interest but were not prepared for the continuing interest.

Individual requests for reprints over the years have far outnumbered those for any article we have published. Because we were still receiving requests for the article 20 years later, we brought it up to date and republished it in the Annual Digest Issue in 1953.

This appearance stimulated another stream of requests. So we recently asked Mr Harper to revise his original article completely. Here's the new version—under the same title as the first one 26 years ago.

When we are asked for a motor that starts or reverses several times per minute, one of our first questions is: "What is the external inertia, or Wk^2, referred to the motor shaft?" All too often this draws a blank look. What we have here is strictly a mechanical function, but its importance is still little understood—or if known, is disregarded. Even though we have been discussing it in print for over 25 years, many mechanical designers seem to have trouble calculating this quantity, and have confused ideas concerning the power required for acceleration. In reality the problem is comparatively simple—it's just kinetic energy.

Every moving body has stored kinetic energy proportional to the product of its mass and the square of its velocity. To increase its velocity you must deliver to it an amount of energy (neglecting losses) equal to the difference in the energy of the body at the final and initial velocities. This means that when large masses in a machine must be accelerated to a high velocity in a short time, the power required may be many times greater that that needed to keep the machine working after the velocity has been attained. Also, changing the mass has much less effect than changing the velocity.

Considering a body of mass M in slugs (weight/32.2),

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Wk^2

moving linearly at a velocity of V ft/sec, the kinetic energy E in ft-lb is:

$$E = 1/2\,MV^2$$

For rotating bodies, the mass actually distributed around the center of rotation is equivalent to the whole mass concentrated at the radius of gyration k. The linear velocity of the concentrated mass at radius k in ft is $2\pi kN$ ft/min, where N is rpm. Dividing by 60 to reduce to ft/sec, and using $W/32.2$ for M, the kinetic energy is

$$E = \frac{Wk^2\,N^2}{5872.86}\ \text{ft-lb}$$

Here, the factor Wk^2 appears. It is merely the weight of the body times the square of the radius of gyration, and is directly proportional to the kinetic or "stored" energy in the body. It is commonly known as "moment of inertia," although strictly speaking, moment of inertia is $Wk^2/32.2$. In usual formulas, however, the factor 32.2 disappears or is absorbed in constants, so that Wk^2 itself remains as a convenient factor.

In considering the torque required for acceleration, the calculated energy E is only the input to the rotating body itself, and has no direct relation to the input to the driving motor during acceleration. It is, therefore, preferable to determine the accelerating torque at the motor shaft. which corresponds to power input to the motor. This torque T is readily determined from the angular acceleration of the body θ in radians/sec/sec, and the moment of inertia I,

$$T = I\,\theta\ \text{lb-ft}$$

Assuming constant torque, θ is the final angular velocity ω divided by the time t in sec required to accelerate from rest. Thus for final angular velocity N,

$$\theta = \frac{\omega}{t} = \frac{2\pi N}{60\,t}$$

Substituting $Wk^2/32.2$ for I and $2\pi N/60t$ for θ,

$$T = \frac{Wk^2}{32.2} \times \frac{2\pi N}{60\,t} = \frac{Wk^2\,N}{307.6\,t}\ \text{lb-ft}$$

This equation assumes constant angular acceleration up to the final velocity of the machine, and is inaccurate if acceleration increases or decreases as the machine gathers speed. But even if the acceleration does vary, this equation is useful in some cases, as will be explained later.

The equation implies starting from rest. If the part is already running at some speed N_1, the torque necessary to increase the speed to N_2 is obtained by substituting N_2-N_1 for N if both speeds are in the same direction. If the speeds are in opposite directions, it is best to calculate in two stages, first from the original speed down to zero, and then from zero up to the final speed. Friction torque and load torque often assist retardation, but oppose motor torque during acceleration.

Torque necessary to accelerate a rotating body depends

HOW SPEED AFFECTS Wk^2 IN A TWO-SPEED DRIVE.

GEAR TRAIN AND EQUIVALENT INERTIAS

	WITH CLUTCH X ENGAGED		WITH CLUTCH Y ENGAGED	
Shaft 1	at motor speed	0.050	at motor speed	0.050
Gear a	at motor speed	0.428	at ¼ motor speed (0.428/4²)	0.027
b	at motor speed	0.400	at ¼ motor speed (0.4/4²)	0.025
c	4X motor speed (0.03 x 4²)	0.480	at motor speed	0.030
d	at motor speed	2.330	at ¼ motor speed (2.33/4²)	0.145
Clutch X	body at motor speed	1.510	at ¼ motor speed (1.51/4²)	0.095
	arm at motor speed	0.280	at motor speed	0.280
Clutch Y	body 4X motor speed (1.51 x 4²)	24.200	at motor speed	1.510
	arm at motor speed	0.280	at motor speed	0.280
Shaft 2	at motor speed	0.050	at ¼ motor speed (0.05/4²)	0.003
	Total Equivalent Wk²	30.008		2.445

directly on the value of Wk^2, the "moment of inertia." When this value is known, the horsepower required for acceleration is

$$HP = \frac{T \times N}{5250}$$

Equivalent inertia

Our concern is for the power required at the motor. As a rule, rotating elements in the machine run at speeds different from that of the motor, and to calculate the torque for a system all components must be reduced to a common base. Since the energy of any part reduced to the motor speed N_m will remain unchanged, the equivalent inertia Wk_e^2 will be

$$Wk_e^2 = Wk^2\left(\frac{N}{Nm}\right)^2$$

In other words, the equivalent Wk^2 of a part running at a speed different from that of the motor is the same as the Wk^2 of that part multiplied by the square of the ratio of its speed to that of the motor. A reasonably large gear reduction between the motor and load minimizes the effect of load inertia on accelerating torque; if the load is geared up, accelerating torque is obviously increased.

While the gear layout shown at left, is not recommended for a drive, it brings out several significant points. With clutch X engaged, gear d drives the body of clutch Y and gear c at 4 times motor speed; the equivalent Wk^2 of these parts becomes a large portion of the total inertia. Gear d has a relatively high inherent Wk^2 and enters the calculations at full value since it runs at motor speed, but c, while inherently small, becomes 16 times as effective because of the 4:1 speed increase.

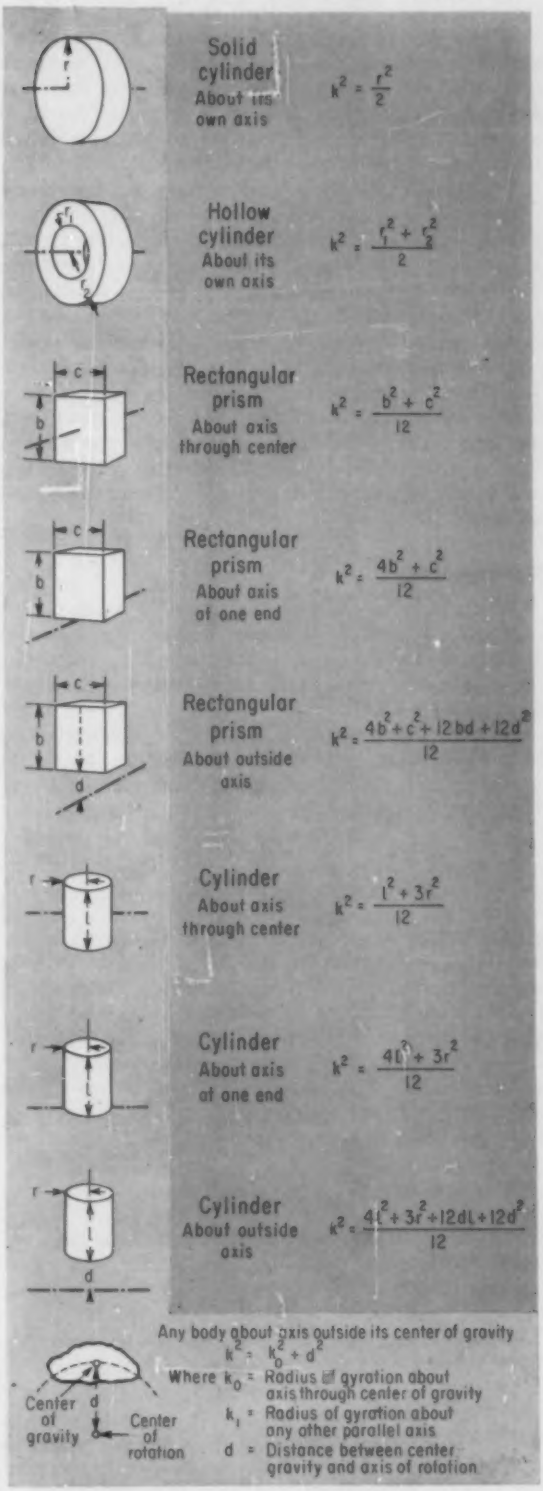
With clutch Y engaged, conditions are reversed. The body of clutch Y represents only 1.51 lb-ft² in the total as compared with 24.2 lb-ft² previously. Also gear d, now running at one-quarter motor speed, has dropped from 2.33 to 0.145 lb-ft².

continued, next page

SYMBOLS

- *E* Kinetic energy, ft-lb
- *I* Moment of inertia, lb-ft²
- *k* Radius of gyration, ft
- *M* Mass, slugs (lb/32.2)
- *N* Angular velocity, rpm
- *T* Torque, lb-ft
- *V* Velocity, ft/sec
- *W* Weight, lb
- ω Angular velocity, radians/sec
- θ Angular acceleration, radians/sec/sec

RADIUS OF GYRATION FOR GEOMETRICAL FORMS.


Solid cylinder
About its own axis
$k^2 = \frac{r^2}{2}$
Hollow cylinder
About its own axis
$k^2 = \frac{r_1^2 + r_2^2}{2}$
Rectangular prism
About axis through center
$k^2 = \frac{b^2 + c^2}{12}$
Rectangular prism
About axis at one end
$k^2 = \frac{4b^2 + c^2}{12}$
Rectangular prism
About outside axis
$k^2 = \frac{4b^2 + c^2 + 12bd + 12d^2}{12}$
Cylinder
About axis through center
$k^2 = \frac{l^2 + 3r^2}{12}$
Cylinder
About axis at one end
$k^2 = \frac{4l^2 + 3r^2}{12}$
Cylinder
About outside axis
$k^2 = \frac{4l^2 + 3r^2 + 12dL + 12d^2}{12}$
Any body about axis outside its center of gravity
$k^2 = k_0^2 + d^2$
Where k_0 = Radius of gyration about axis through center of gravity
k_1 = Radius of gyration about any other parallel axis
d = Distance between center gravity and axis of rotation
Center of gravity
Center of rotation

Wk^2

When the speed is reduced a quarter or more, shafts and other parts can often be neglected. Shaft 2 represents only 0.003 and gear *b* 0.025 as compared with 0.050 and 0.400 lb-ft with clutch *X* engaged. Actually the shafts and gears *a* and *b* are negligible in both situations because of the importance of the clutch body.

In designing gearing for snappy operation or reversing, eliminate all uselessly turning parts; avoid increase in speed in the train; and keep the inertias of all rotating parts to a minimum. A given part may have widely differing inertia effect, depending on how it is used in the gear train. For example, the table drive for a boring mill may have a number of different gear ratios; therefore the equivalent inertia of the table referred to the motor shaft will be different for each gear combination and can vary over a considerable range. The external inertia may be as much as 800% of the motor inertia for high table speeds, or as little as 50% for slow speeds. Therefore both accelerating and decelerating torque performance will vary at different speeds.

Linearly moving parts

When some of the inertia is stored in linear motion of parts, the accelerating torque for the combination of linear and rotary motion is determined by converting linear to rotary inertia based on the speed at the motor shaft.

Equating rotary energy $\frac{1}{2} M (2\pi kN)^2$ and $\frac{1}{2} MV^2$ for linear movement, and substituting $W/32.2$ for M to obtain pounds, the equivalent rotary inertia Wk_e^2 of the linearly moving parts is

$$Wk_e^2 (2\pi N)^2 = WV^2$$

$$Wk_e^2 = W\left(\frac{V}{2\pi N}\right)^2 = \frac{W}{39.48}\left(\frac{V}{N}\right)^2$$

or the weight of the part in pounds multiplied by the square of the ratio of the velocity of the part in fpm, and 2π times the speed of the motor in rpm. After adding the equivalent Wk_e^2 of all parts, the torque and horsepower required to accelerate can be calculated as before.

Take the reciprocating table of a metalworking planer as an example. The table weighs 4000 lb and at top speed runs 300 fpm, corresponding to a motor speed of 1200 rpm. The equivalent inertia is:

$$Wk_e^2 = 4000\left(\frac{300}{2\pi\ 1200}\right)^2 = 4000\left(\frac{1}{2\pi 4}\right)^2 = 6.32$$

Hence the equivalent Wk^2 of the planer table (but not including the gears) would be 6.32 lb-ft^2. For the total equivalent machine inertia, the gearing inertia is reduced to the motor speed, and is added in.

This relationship for Wk_e^2 applies only when the velocity *V* bears a constant relation to the motor speed *N*. It cannot be applied when a motor running at constant speed drives reciprocating parts with a varying velocity that attains a maximum value in one direction, retards to zero, and then attains a maximum in the opposite direction.

Radius of gyration

Calculating the weight is simple, but determining the radius of gyration *k* is not so easy. To simplify calculations, the accompanying chart includes the square of the radius of gyration for common forms of bodies and various axes of rotation.

While the actual rotating body will seldom correspond exactly to any of these forms, any body may be resolved into parts that closely agree with one of the basic forms. A spoked flywheel can usually be separated into a rim (hollow cylinder), spokes, (cylinder about axis at end) and a hub (hollow cylinder). If the flywheel is webbed, the web would also correspond to a hollow cylinder. Each separate calculation is simply the weight of the particular part multiplied by the square of the *k*.

Ordinarily the radius is in feet and the weight in pounds, although lb-in., or even oz-in. are used. The units used should always be specified.

It may not be necessary to calculate each individual part precisely. If a flywheel is large in diameter and has a heavy rim it is usually sufficient to calculate the rim and then add a percentage for the spokes and hub. For motor armatures, calculations can be based on weight and outside diameters; typical values are tabulated below for a range of NEMA frame sizes.

Another aid in calculation for steel disks is a tabulation of Wk^2 per in. of length. Values for diameters from 1 in. to 200 in. dia are tabulated at right. Thus, a part made up of cylinders and plates can be estimated quickly. Note also that a hub, even though filled with shaft, can fre-

TYPICAL Wk^2 VALUES FOR OPEN SQUIRRELCAGE INDUCTION MOTORS

NEMA Frame	Wk^2	NEMA Frame	Wk^2
182	0.11–0.12	326	5.6–7.3
184	0.13–0.18	364	8.6–13.4
213	0.35–0.37	365	10.2–15.7
215	0.48–0.50	404	15.5–24
254	1.2–1.7	405	20–30
256	1.5–2.0	444	32–46
284	2.6–3.7	445	41–57
286	3.3–4.7	504	64–67
324	4.6–6.0	505	68–81

Higher values generally apply for 6 poles and more; 2-pole motors are 60-75% of minimum values shown.

Totally enclosed fan-cooled motors in 284 frame and larger are 120-140% of open motors.

Individual motor designs vary; motor manufacturer can supply exact values if needed.

quently be neglected. This same method can be used for gears, assuming the teeth as 40% of the hollow cylinder represented by the root tooth diameters. Values in the table can be corrected for materials other than steel.

In arriving at moments of inertia, the energy stored in rollers and other rotating parts that serve no useful purpose should be overestimated rather than underestimated. On the other hand, for a flywheel used to reduce peak loads, the inertia should be underestimated. But when determining capacity of the motor controller and estimating

INERTIA OF SOLID STEEL CYLINDERS, 1 IN. LONG

Dia, in.	Wk^2	Dia, in.	Wk^2	Dia, in.	Wk^2	Dia, in.	Wk^2	Dia, in.	Wk^2
1	0.000192	41	543.9	81	8286	121	41262	161	129336
2	.00308	42	598.8	82	8703	122	42643	162	132579
3	.01559	43	658.1	83	9135	123	44059	163	135883
4	.049278	44	721.4	84	9584	124	45510	164	139249
5	.12030	45	789.3	85	10048	125	46995	165	142676
6	.2494	46	861.8	86	10529	126	48517	166	146166
7	.46217	47	939.3	87	11028	127	50076	167	149720
8	.78814	48	1021.8	88	11544	128	51672	168	153339
9	1.262	49	1109.6	89	12077	129	53305	169	157022
10	1.924	50	1203.07	90	12629	130	54978	170	160772
11	2.818	51	1302.2	91	13200	131	56689	171	164588
12	3.991	52	1407.4	92	13790	132	58440	172	168472
13	5.497	53	1518.8	93	14399	133	60231	173	172424
14	7.395	54	1636.7	94	15029	134	62063	174	176446
15	9.745	55	1761.4	95	15679	135	63936	175	180537
16	12.61	56	1893.1	96	16349	136	65852	176	184699
17	16.07	57	2031.9	97	17041	137	67811	177	188933
18	20.21	58	2178.3	98	17755	138	69812	178	193239
19	25.08	59	2332.5	99	18490	139	71858	179	197618
20	30.79	60	2494.7	100	19249	140	73948	180	202071
21	37.43	61	2665.2	101	20031	141	76083	181	206599
22	45.09	62	2844.3	102	20836	142	78265	182	211203
23	53.87	63	3032.3	103	21665	143	80493	183	215883
24	63.86	64	3229.5	104	22519	144	82768	184	220640
25	75.19	65	3436.1	105	23397	145	85091	185	225476
26	87.96	66	3652.5	106	24302	146	87463	186	230391
27	102.30	67	3879.0	107	25232	147	89884	187	235386
28	118.31	68	4115.7	108	26188	148	92355	188	240461
29	136.14	69	4363.2	109	27173	149	94876	189	245619
30	155.92	70	4621.7	110	28183	150	97449	190	250858
31	177.77	71	4891.5	111	29222	151	100075	191	256182
32	201.8	72	5172	112	30289	152	102750	192	261589
33	228.2	73	5466	113	31385	153	105482	193	267081
34	257.2	74	5772	114	32511	154	108268	194	272660
35	288.8	75	6090	115	33667	155	111107	195	278325
36	323.2	76	6422	116	34853	156	114002	196	284078
37	360.7	77	6767	117	36071	157	116954	197	289920
38	401.3	78	7125	118	37320	158	119962	198	295852
39	445.3	79	7498	119	38601	159	123028	199	301874
40	492.78	80	7885	120	39914	160	126152	200	307988

Wk^2 in lb-ft^2; multiply by 144 to get lb-in.^{2}. Moving decimal point one place in diameter shifts decimal point four places in same direction in Wk^2. Based on steel at 487 lb per cu ft. For materials other than steel, divide Wk^2 in table by 487, and multiply by: magnesium, 109; aluminum, 169; cast iron, 442; brass, 527; bronze, 546; copper, 555.

Wk^2

the power required to start from rest in a given time, all inertias should be overestimated.

Some practical considerations

Now, having seen what a highly important part the moment of inertia plays in problems involving acceleration, and having discussed ways for determining this value, here are some practical points. Of the two factors making up the inertia, the radius is a squared quantity, and therefore has a greater effect on inertia than the weight. Doubling the weight merely doubles the inertia; doubling the radius increases the inertia four times. For high-speed parts frequently started or reversed, first keep the diameters small; next, reduce the weight. And, even if high speed is not involved, inertia may become important if the number of reversals or starts exceeds eight or ten per minute.

In determining the horsepower to accelerate a mechanism, the inertia factor enters into the calculation only once, but the speed is there twice, or as a squared quantity. Thus, though the value of Wk^2 should be kept low, it does not cause as much trouble as high speed.

Reversing motors should run at speeds under 1800 rpm and 900 rpm is generally more desirable than 1200 rpm. The horsepower necessary to accelerate the 900-rpm motor is only ¾ as much as required for the 1800-rpm motor plus an allowance for the somewhat greater Wk^2 of the slower speed motor. Usually, but not always, the gain from the reduced speed is greater than the loss from increased Wk^2. However, at the slower speed, the external inertia becomes a bigger percentage of the total. Calculations are usually necessary to arrive at the best combination of motor speed and load speeds.

Because inertia varies with the square of the speed, the first reduction in a gear train following the motor should be as large as possible. With a large initial reduction it may be possible to disregard the inertia of all parts beyond the first or second reduction. For example, with a single 4:1 reduction next to the motor, anything beyond the motor shaft will have only 1/16 the effect.

Importance of light weight

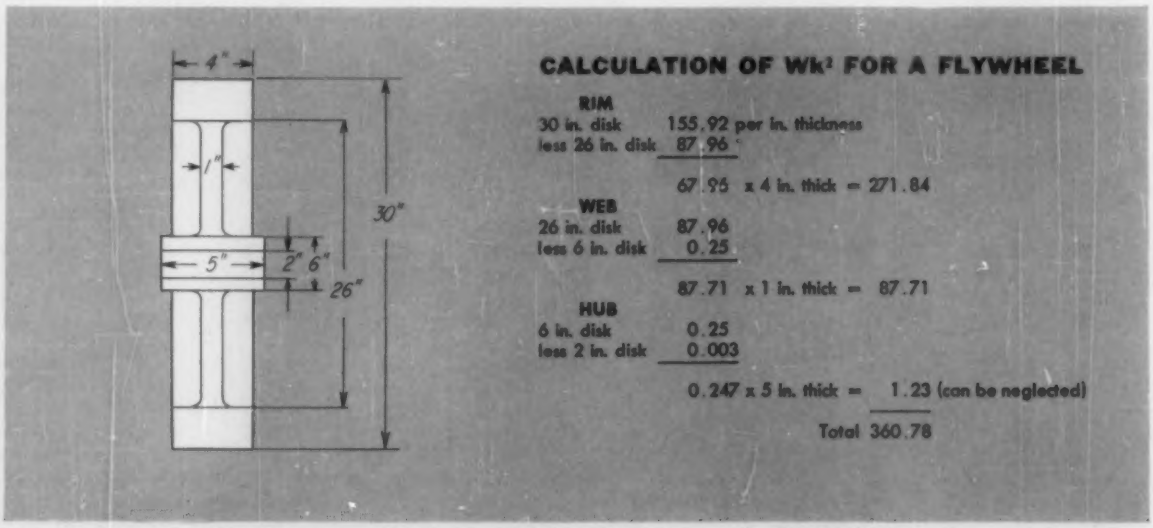
On rapid-reversing drives, all parts on the motor shaft, such as couplings or pinions, should be kept as small as possible, and lightweight alloys are often desirable. Also, a high initial ratio will keep pinion diameter small. Sometimes on rapid-reversing or frequent-starting cycles a smaller motor will reduce overheating. If inertia of the motor rotor is a large part of the acceleration load, most of the work done may be in reversing the motor. In specifying a motor for reversing service, give the equivalent inertia and speed at the driveshaft, and the loading over the cycle. Then it is possible to pick the motor with the best torque characteristics for the job.

When the motor speed is geared up to the machine, the inertia of each part of the drive must be calculated with care. Merely a 2:1 increase in speed means that the inertias of the higher speed parts are multiplied by four, and this may make the equivalent external inertia greater than that of the motor.

Torque characteristics

With the horsepower and the equivalent Wk^2 established, the type of motor to select depends on characteris-

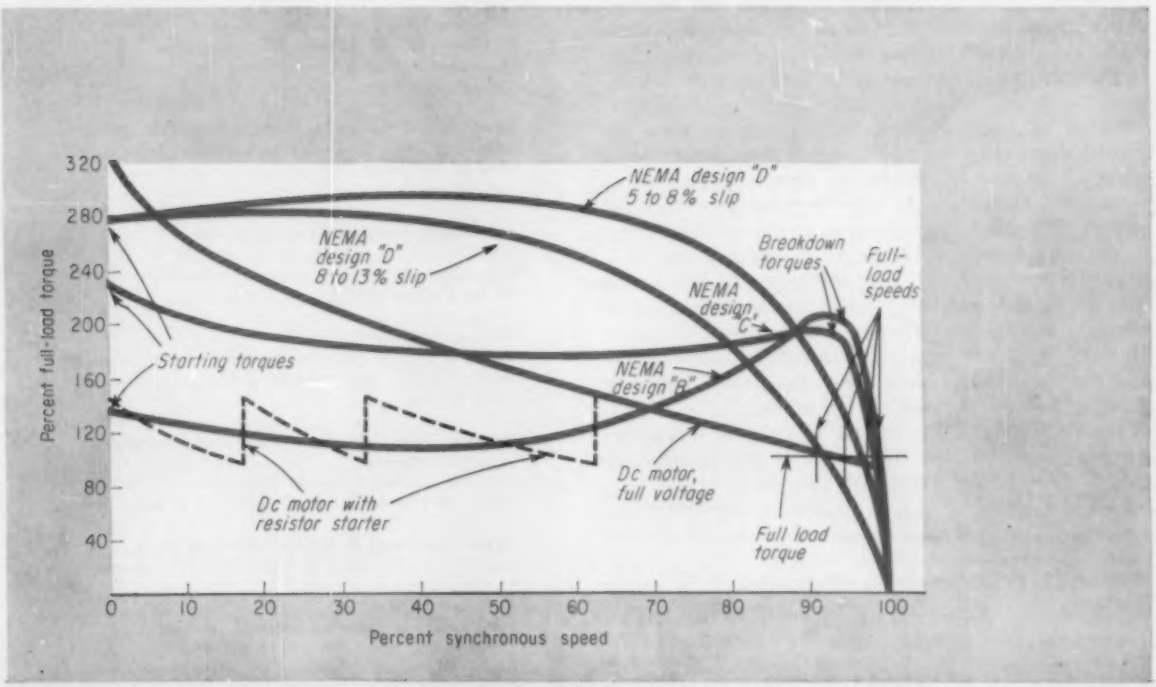
text continued on page 48



HOW TABLE OF INERTIAS for steel cylinders is applied in calculating inertia of a flywheel.

APPROXIMATIONS FOR MOMENTS OF INERTIA

NAME OF PART	MOMENT OF INERTIA
Flywheels (but not belt pulleys)	1.08 to 1.15 times rim alone
Flywheel (based on weight and OD)	2/3 of total weight concentrated at the outer circumference
Spur or helical gears (teeth alone)	40% of hollow cylinder of same limiting dimensions
Spur or helical gears (rim alone)	Hollow cylinder of same limiting dimensions
Spur or helical gears (weight and pitch diameter known)	0.60 of total weight concentrated at pitch circle
Spur or helical gears (total)	1.25 times the sum of teeth plus rim
Motor armature (based on weight and OD)	Ratio of radius of gyration to outer radius: Large slow-speed motor..... 0.75 to 0.85 Medium-speed dc or induction motor..... 0.70 to 0.80 Mill-type motor..... 0.60 to 0.65



TORQUE-SPEED CURVES for typical motors. **NEMA Design D motors with high average torque are usually best for reversing or rapid acceleration.**

Wk^2

tics and design of motors. The three principal types of squirrelcage induction motors are: normal torque, normal starting current, NEMA design B; high torque, normal starting current, low slip, NEMA design C; high torque, high slip, relatively low current, NEMA design D.

NEMA design B is a general-purpose motor suitable for only a limited number of reversals per minute or for infrequent starting. Design C is used with heavy inertia loads, and for moderately frequent reversal if normal running load is appreciable, or where heavy starting loads are encountered with low running load. Design D motors are selected for reversing applications where the number of reversals is frequent, and where the major portion of the load is in reversing the motor rotor itself. With its high slip, this motor is well adapted to machines such as punch presses; it can slow down under load and allow the flywheel to deliver some kinetic energy to the load.

Torque-speed curves

Torque-speed curves for these types of motors are shown on the preceding page. In general, the motor with highest average torque throughout the accelerating period (not necessarily the highest torque) is best suited for applications requiring frequent acceleration. When accelerating time is limited the highest average torque during acceleration requires the least time to bring the load up to speed.

To find the available torque of a motor when the actual torque-speed curves are not at hand, it is customary to use an average of the starting, breakdown and full-load running torques. These data usually are available. When only the starting and full-load torques are given, the average of these two values can usually be used safely in calculations.

Torque calculations assume that the torque—hence the angular acceleration—remains constant throughout the acceleration period. If essential to allow for variation in torque, the torque can be calculated for increments of velocity as the machine comes up to speed—on the assumption that acceleration will be practically constant over small steps. Or the progressive rate of change of velocity with time during the accelerating period may be determined to obtain a more precise solution of the torque equation. However, with the inexactness of data usually available and the variability of conditions, the average torque is generally sufficient without any correction.

For a dc motor with a starting resistor, the torque can be kept nearly constant by design of the resistor and starter. The starting current and the current of each successive step is limited to approximately 150% of full-load current, and the next block of resistance is cut out at about normal full-load current.

Moral: To get help from the motor specialist, be sure to give him the Wk^2 referred to the motor shaft.

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EDITOR'S NOTE:
Problems in selecting motors for starting and reversing high-inertia loads have been approached from many angles in earlier articles:

Duty Cycle from Motor-winding Resistance,
Jan 25 '60, p 64—Describes method giving measurements while motor is driving the load.

Prediction of Induction-motor Performance,
Dec 21 '59, p 42—Precalculated curves shortcut the math needed for evaluating loads not described in motor catalogs.

Four Ways to Stop a Motor,
July 6 '59, p 60—Compares mechanical, plugging, dynamic and capacitor braking.

Let the Load Be Your Guide When Selecting Polyphase Motors,
Aug 18 '58, p 58—Tables match load characteristics with available motor designs in terms of torque, slip and duty cycle.

New NEMA Standards for Motors,
Feb 3 '58, p 54—A motor designer explains the changes in ratings introduced by new NEMA standards.

Controlled-acceleration Devices,
Mar 3 '58, p 75—Seven answers to the problem of teaming a high-acceleration power source with a slow-starting machine.

Matching Drives to Loads,
Mid-Sep '59, p 428—Matching natural characteristics of drive output to load requirements, for adjustable-speed drives.

Lower Speed Motors for High-performance Drives,
Sep 16 '57, p 96—Shows how a lower base speed is as important as decreasing inertia in reducing energy losses during starting or stopping.

Calculating Mass Moments of Inertia,
Jan '56, p 215—Two nomograms aid in calculations for cross-sections of any shape and for any material.

Driving High-inertia Loads,
Apr '56, p 142—Relates flywheel inertia to motor design, speed-torque characteristics under cyclic loads.

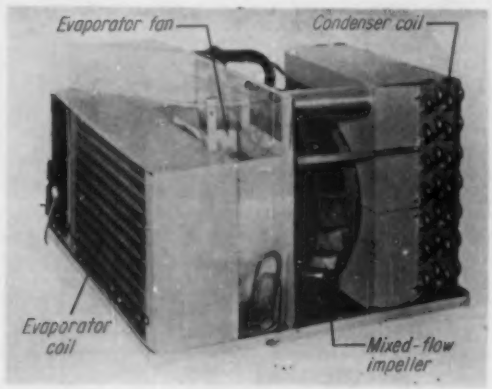
Importance of Duty Cycle in Selecting Polyphase Induction Motors,
Nov '54, p 174—Presents a detailed analysis of NEMA Design B, C and D torque and speed ratings.

Determination of Motor Hp from Duty Cycle,
Aug '50, p 131 and Sep '50, p 135—Offers methods of calculating duty cycle.

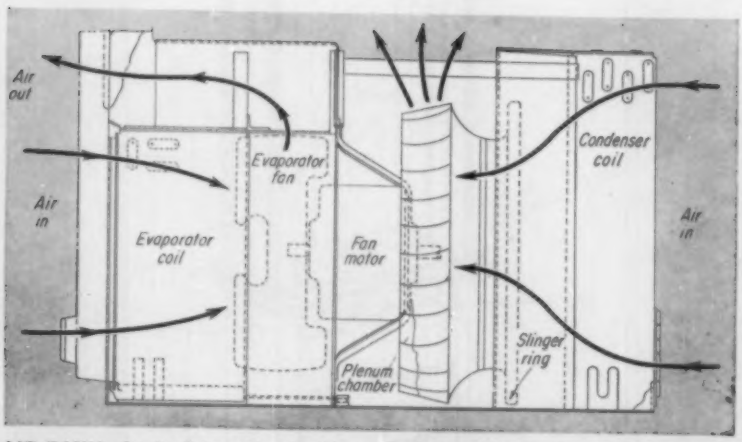
Here's Help in Selecting the Right Motor,
Oct 13 '58, p 86—A PRODUCT ENGINEERING bibliography of 50 articles from the past six years covering all motor types and applications.

Mixed-flow Impeller Solves Space Problem

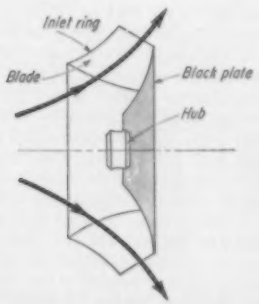
Lower noise level, reduced power consumption, need for fewer parts—these are benefits of the compromise impeller. It combines characteristics of axial and radial units.



ROTATIONAL SPEED of axial fan used on the room side (evaporator side) of air conditioner was set at 1080 rpm to insure low noise level. Single motor drives the impellers on both evaporator and condenser side. This requires the condenser fan to deliver the required air through its coil at 1080 rpm. Axial fans capable of handling required volume at this speed were too large for the available space. Two factors dictated use of the mixed-flow impeller—higher efficiency resulting in a smaller fan for the same load; space savings resulting from elimination of the housing required with an axial-flow unit.



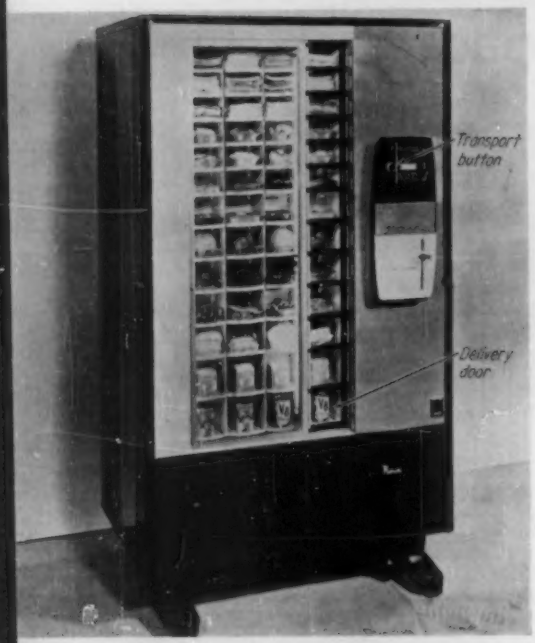
AIR PATH of mixed impeller combines the large flow area on the intake side of the axial with peripheral discharge of the radial-flow fan. This is achieved by using a compound blade curvature with both axial and radial components which discharge air conically. Impeller has 19 blades, mounted between the curved inlet ring and back plate. Pressure-flow characteristics are uniform in shape, without the stall-recession dip usually found with axial and centrifugal types. The combination produces ideal conditions in the range where the majority of heating and cooling appliances operate.



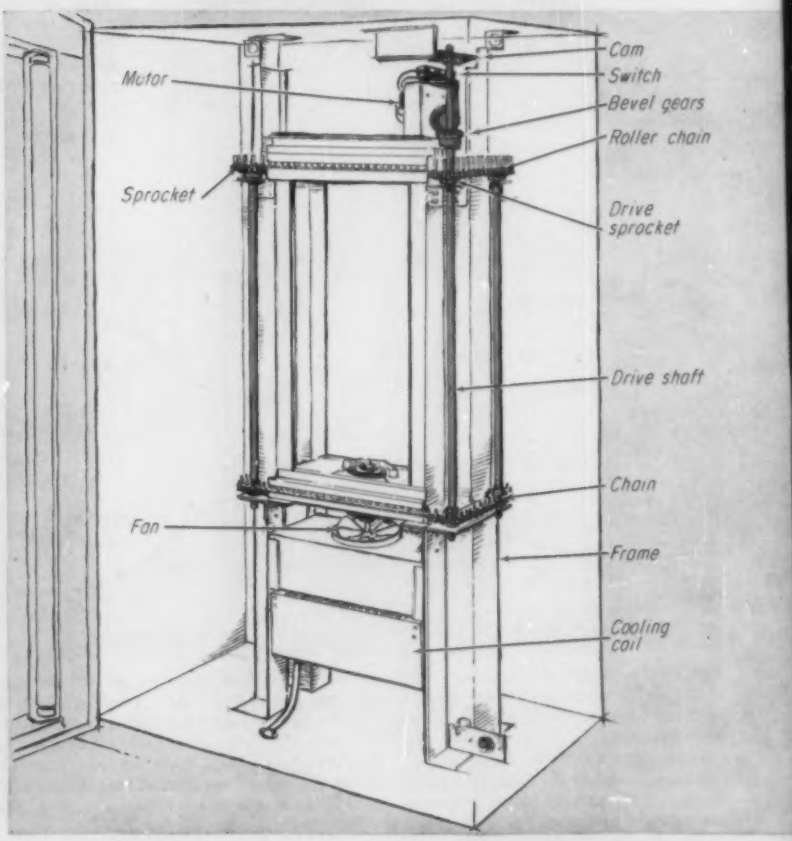
PS . . . Its use in room air conditioners permits this smaller impeller to do double duty—in less space. Also, its lower operating speed and reduced turbulence give a marked drop in the noise level—a familiar problem when moving large volumes of air through restricted spaces. Mixed Flow Impeller Wheel, Type HE, produced by Torrington Mfg Co, Torrington, Mass, is used in 1960 Carrier Room Air Conditioners, produced by Carrier Corp, Syracuse, NY. For more design details see "Mixed-flow Impellers Enter Air-moving Field," Jan 5 '59, p 56.

Automated to Sell a la Carte

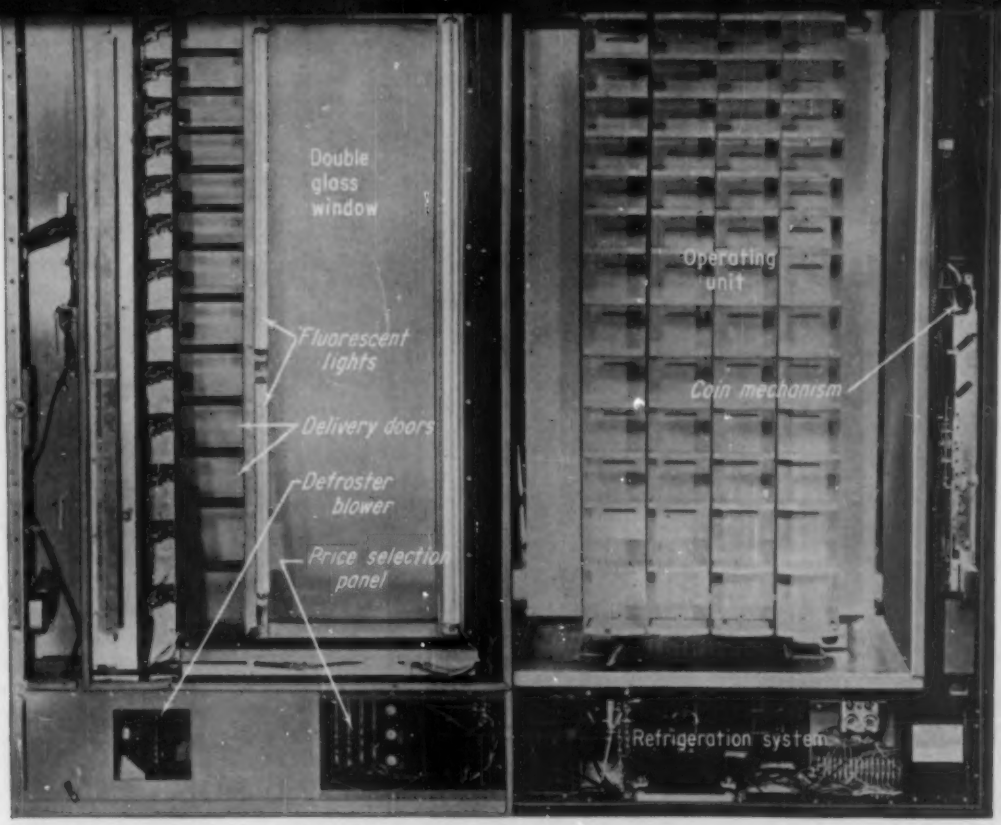
Electromechanical salesman—combining refrigerator with merchandiser—has carousel that offers choice of 130 items. Double glass and defroster system keep display windows clear at all times.



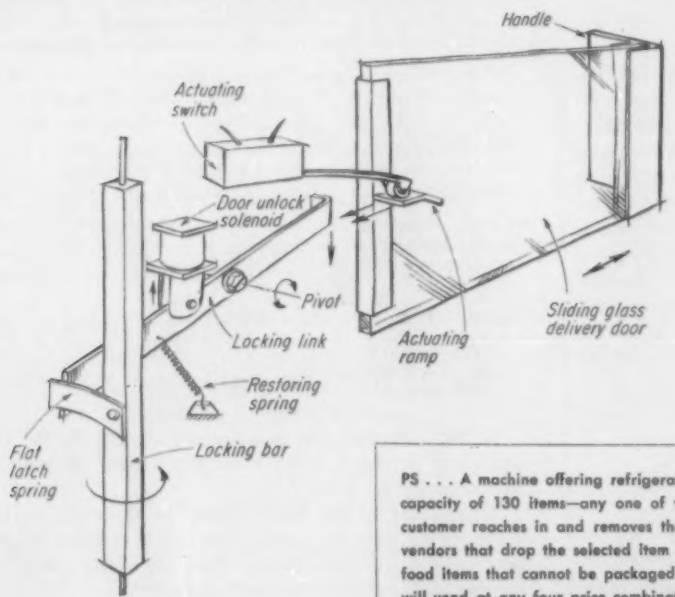
LOADED MERCHANDISER displays 52 items in four columns of 13 items each at all times. Pressing the transport button brings the other 78 items to the display or delivery position. Price tabs on the glass doors in the delivery column indicate how much must be deposited to open the door. Once a customer drops the money and chooses his item, operation is virtually foolproof. By opening one of the 13 delivery doors, circuits are energized to collect the coins deposited and lock all other doors. Once opened, the selected door remains unlatched until the transport button is depressed.



CAROUSEL TRANSPORTS COLUMNS to delivery position by roller chains following a rectangular path. The columns are supported by tabs which slip over extension pins on both upper and lower chains. One motor atop the carousel drives both chains through bevel gears and sprockets mounted on the drive shaft. Cam at the top of driveshaft actuates microswitch that controls the motor for positive column positioning. This is required so that the columns will be accurately aligned behind the delivery doors when the carousel stops.



COMPARTMENTATION OF MERCHANDISER simplifies operation, maintenance, and assembly. Cabinet door contains the delivery doors and their associated mechanism, defroster blower, vendor price-selection panel, double-glass window, and fluorescent lights. Cabinet proper is divided into three compartments—for operating unit, refrigeration system, and coin mechanism. The operating-unit compartment is refrigerated by a cooling coil and fan mounted on the carousel support frame. Refrigeration system is a sealed compressor and condenser coil mounted in the base compartment. Narrow vertical section beside the operating compartment holds the removable coin mechanism and coin bucket.



DELIVERY-DOOR SYSTEM is heart of merchandiser operation. When the correct coins are deposited and a delivery door is opened approximately ⅛ in., the actuating switch energizes the unlock solenoid, the locking-bar solenoid and the vend circuit. Vend circuit dumps coins deposited into the coin bucket and clears the coin mechanism. Unlocking solenoid pivots locking link, allowing door to open fully. Locking-bar solenoid rotates the bar and locks the other 12 delivery doors. Door is closed by a spring-loaded roller-follower but does not relock until transport button is pressed.

PS . . . A machine offering refrigerated foods and beverages of all types, vendor has capacity of 130 items—any one of which may be selected. Another advantage: the customer reaches in and removes the item by hand. This contrasts with gravity-feed vendors that drop the selected item into a delivery hopper—eliminating sale of many food items that cannot be packaged to withstand rough handling. The new machine will vend at any four price combinations, ranging from 5 to 50 cents, selected by the vendor; accepts any combination of nickels, dimes and quarters. "All-purpose Merchandiser", Model 147, is produced by Rowe Mfg Co Inc, Whippany, NJ.

COMBINED LOADS ON BEAMS

. . . . stressing the other axis

Our May 16 article, "Faster Analysis of Combined Loads on Beams," inspired an interesting reaction by W. A. Welch, consulting engineer of Danbury, Conn.

In his view, Victor Klein's "very useful analytical tool" needs closer examination—how would the beam behave in some other plane than that described in the article?

Believing Welch's comments will be of general interest, we present his letter, along with the basic equations supplied in Klein's article. This is then followed by a reply from Klein—a mechanical engineer who is serving as foreign-language consultant to the Library of Congress, Washington, DC.

MR WELCH WRITES:

The article by Victor Klein is a fresh and certainly useful approach to a tedious analysis. However, certain limitations of the procedure were not mentioned, and this could lead the unwary user into grossly incorrect results.

For example, the method is applicable without modification only to beam cross-sections having a radius of gyration about an axis in the plane of the transverse loads at least equal to that about the perpendicular axis. Otherwise, the beam may appear safe in this analysis, when it is unstable as a column for buckling in some other plane than the one containing the bending loads. Indeed, example 1 illustrates this clearly. Taking the section properties of an American Standard I-beam as listed by Mark's nearest the example, the least radius of gyration can be found as:

$r = \sqrt{I/A} = \sqrt{1.8/3.61} = 0.705$ in.

Then, for pin-ended conditions

$L'/r = 200/0.705 = 284$
$F_c = 286\ (10^6)/(L'/r)^2 = 3530$ psi (ref. Air Force-Navy-Commerce Bulletin ANC-5)
$f_c = 24000/3.61 = 6650$ psi
$MS = (F_c/f_c) - 1 = (3530/6650) - 1 = -0.469$

The negative margin of safety in lateral buckling contrasts sharply with the innocent-looking maximum stress of 10,840 psi.

Nowhere in the article is the behavior of short columns mentioned, although the critical buckling loads of such members can be appreciably less than indicated by the long-column equations.

Again referring to ANC-5, take the case of a beam-column consisting of 2024-T3 tube 1.0 dia x .065, simply supported at both ends and with a concentrated load at mid-span carrying axial compression:

For L = 13 in. $A = 0.191$ sq. in. $I = 0.021$ in.^{4}
$r = 0.331$ in.
$L'/r = 39.3$
$F_{co} = 42{,}000\ (1 + 42{,}000/200{,}000) = 50{,}800$ psi (ref table 3.21 ANC-5)

$(L/r)_w = 1.732\,\pi\sqrt{E/F_{co}} = 78.4$—at transition to short column behavior

$$F_c = F_{co}\left(1 - \frac{.385\,L/r}{\pi\sqrt{E/F_{co}}}\right) = 23{,}800 \text{ psi}$$

$P_cr = 33{,}800\ (0.191) = 6460$ lb
$P_b = 135$-lb bending load
$P_c = 5000$-lb compression load

By conventional analysis:

$M_b = PL/4 = 439$ in.-lb primary bending moment
M_a = bending moment due to axial load $= P_c y$
$M'_b = M_b + M_a$ = total bending moment
$y_b = P_b L^2/48\,EI = 0.0281$ in. due to bending load
$y_a = y_b\,(\sec L/2\sqrt{P/EI} - 1)$
$= 0.0226$ in. due to compression (ref Timoshenko and MacCullough, art 76).
$y = y_b + y_a = 0.0507$ in. total deflection
$M_a = 5000\ (0.0507) = 253$ in.-lb secondary bending moment
$M'_b = 692$ in.-lb total bending moment
$R_b = f_b/F_b = (M'_b\,d/2\,IF_b) = 0.2255$ (ref fig 3.321, ANC-5)
$R_c = f_c/F_c = 0.774$
$MS = (1/R_b + R_c) - 1 = 0.0$

By Klein analysis:

$M_x = 439$ in. lb
$S = \pi^2\,EI/L^2 = 12{,}900$ lb
$S/P_c = 12{,}900/5000 = 2.58$
$\rho = 1/(S/P_c) - 1 = 0.633$
$k_x = 0.822$ (Table 1)
$N_x = M_x\,(1 + k_x\,\rho) = 666$ in.-lb
$F_x = (N_x - M_x)/P_c = 0.0454$ in.
$R_b = 0.217$
$R_c = 0.387$
$MS = (1/.604) - 1 = -0.656$

In this case, moment is underestimated by 3.7%, and deflection by about 10%, while the margin of safety is overestimated by 65%.

This limitation can be recognized by the Euler critical stress approaching the elastic limit as the column slenderness ratio is reduced. Various data are widely published for use in the analysis of short columns.

When the appropriate range of application is clearly indicated, a highly simplified procedure such as Mr. Klein's can be a very useful analytical tool.

THE AUTHOR REPLIES:

I am pleased to have Mr Welch's comments. The purpose of my method is to replace the time-consuming conventional procedure (of integration of the differential equation of the elastic curve $EI\ d^2F/dX^2 = -N_x$) by a rapid and simple procedure without sacrificing the accuracy. Both methods (mine and the conventional) are based on the same assumptions of the theory of the plane flexure, and therefore the range of their application is the same; that is clear from the whole content of the article where the two methods are constantly compared. The range of application of the conventional method is well known to everyone concerned, and therefore I did not stress this question in my article.

The examples were used only to explain the application of my method, and do not represent the complete analysis of the beams. The problem of stability of the beam in another plane (referred to by Mr. Welch in my example 1) is out of the scope of my article, as it is out of the scope of the conventional method too. If one would use the conventional method, he would get approximately the same results as I got, and, in order to examine the stability (buckling) in the plane of the least moment of inertia, he should use (as Mr Welch did) other methods. The wide-flange beam I used in example 1 has the least radius of gyration $r_{min} = 0.90$ in., and the margin of safety would be MS $= -0.145$; Mr Welch evidently is comparing results for a beam different than the wide-flange beam I used.

I did not mention in my article the behavior of short beams under combined loading because right in this field is an exceptionally high degree of agreement between the two methods. In order to prove that, we shall take Mr Welch's example and calculate more accurately for the purpose of comparison; the values of M, Y, N and F are calculated for the section in the middle of the span:

My method: $M = 439$ in.-lb; $S = 12{,}880$ lb; $S/P_c = 2.275$

$\rho = 0.635 \qquad k = 0.822 \qquad k\rho = 0.522$

$N = 439 \times 1.522 = 668$ in.-lb

$F = (668 - 439)/5000 = 0.0458$ in.

Conventional method:

$$F = Y3\ (\tan h - h)/h^3;\quad N = \frac{M \tan h}{h}$$

where $h = L/2\ \sqrt{P_c/EI} = 0.982$; $\tan h = 1.495$

then $N = 439 \times 1.495/0.982 = 439 \times 1.522 = 668$ in.-lb

$F = 0.0281 \times 3 \times 0.513/0.947 = 0.0456$ in.

This shows that the two methods are very much in agreement.

BASIC EQUATIONS

$$\frac{F_X}{Y_X} = \mu = \frac{1}{1 - P_c/S};\ \text{or}\ F_X = \mu Y_X = Y_X \frac{S}{S - P_c} \tag{1}$$

$$N_X = M_X + P_c F_X = M_X + P_c \frac{S}{S - P_c} Y_X \tag{2}$$

$$Y_X = \frac{M_X L^2}{\alpha EI} \psi \tag{3}$$

$$S = \frac{\pi^2 EI}{L^2} \tag{4}$$

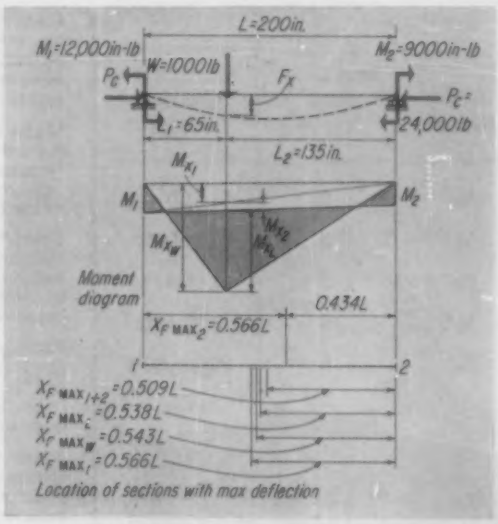
$$N_X = M_X (1 + k_X \rho) \tag{5}$$

$$k_X = \frac{\pi^2}{\alpha} \psi \tag{6}$$

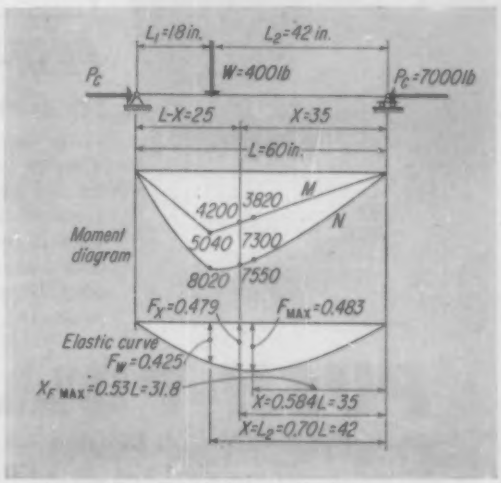
$$\rho = \frac{P_c}{S - P_c} = \frac{1}{S/P_c - 1} \tag{7}$$

$$F_X = \frac{M_X}{P_c} (k_X \rho) \tag{8}$$

$$F_X = \frac{N_X - M_X}{P_c} \tag{9}$$



I-beam with loads used in example 1



Tubing with loads used in example 2

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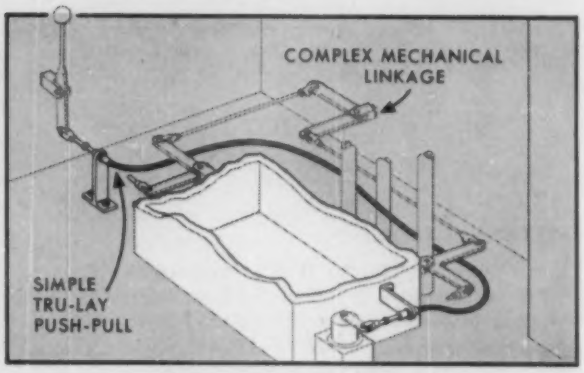

Sizes and Operating Heads to Fit Your Design

Control Dimension	Minimum Recommended Radius in Inches	Maximum Input Load in Pounds (Dependent on Travel)
3/32"	2	30
1/8"	3	65-125
3/16"	5	115-175
1/4"	6	300-600
5/16"	8	700-1,000

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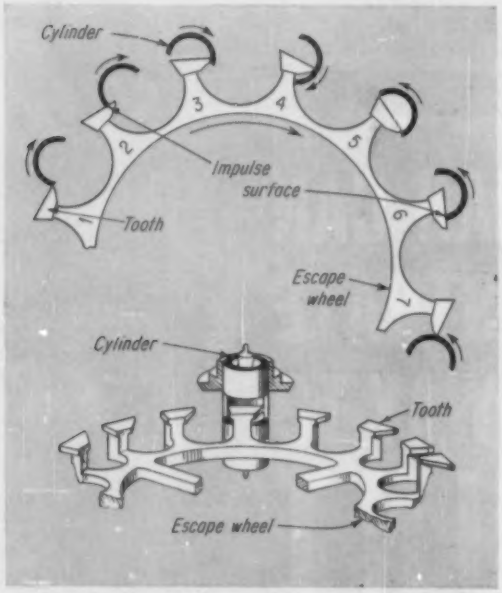
ACCO

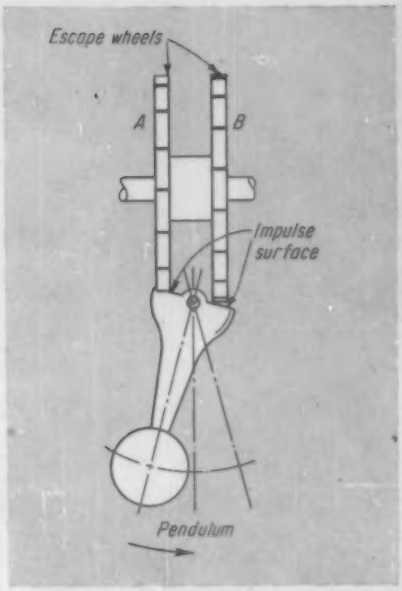
7 More Escapements

Another selection of these ingenious mechanical components for use in control systems (6 others were presented in the June 13 issue).

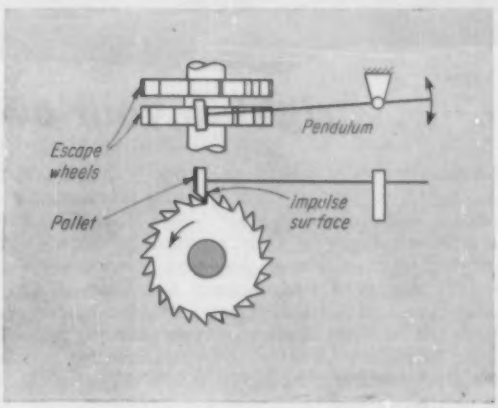
FEDERICO STRASSER
Mankowitz & Strasser
Santiago, Chile



1 CYLINDER. Tooth of escape wheel and cylinder (balance-wheel shaft) are shown in seven positions. Tooth has been locked (1) and is about to enter cycle. Tooth is providing impulse (2) by sliding action along cylinder lip. Escape wheel is locked while cylinder rotates clockwise (3) to its limit (4), then starts back (5). As tooth starts forward, impulse is again imparted (6) to cylinder lip. Second tooth is locked (7) during period of backswing.

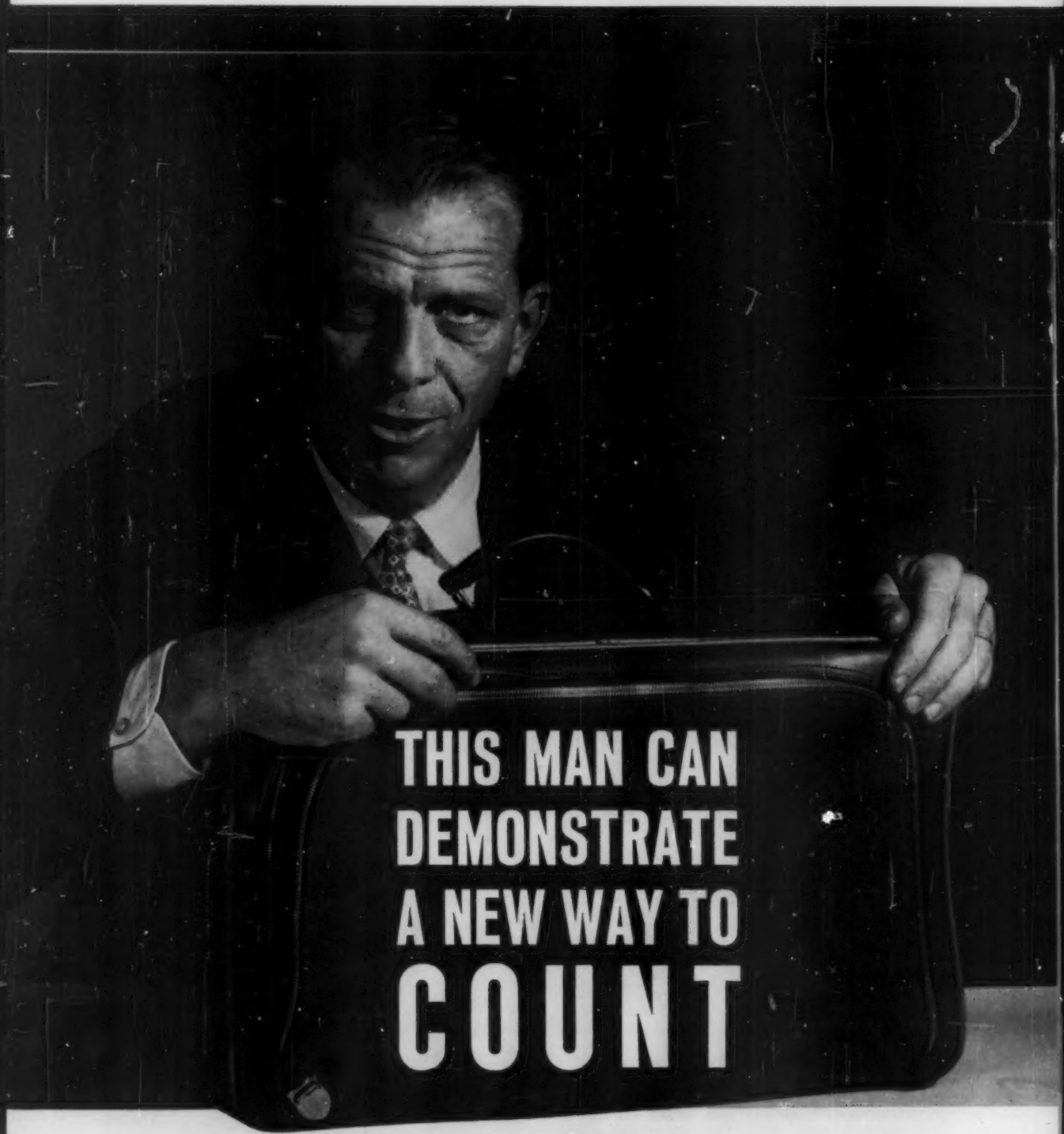


2 DOUBLE RATCHET. Two escape wheels are mounted on a common axis and pinned together so teeth are aligned with a half-pitch distance between them. Drawing shows pendulum in its extreme left position, with its impulse surface locking a tooth of the escape wheel *A*. As pendulum starts to right, escape wheels start to turn, imparting a push to the pendulum. As it approaches its extreme right position, pendulum again stops the escape wheels, by engaging a tooth on wheel *B*, then receives a second impulse as it starts toward the left.



3 HIGH-SPEED DOUBLE RATCHET. Same principle as in 2, but used with a small-mass pendulum. Speeds to 50 beats per second can be obtained.

continued on page 55



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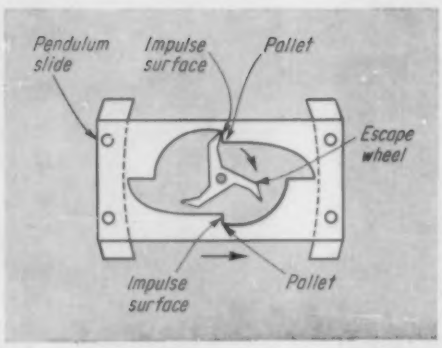
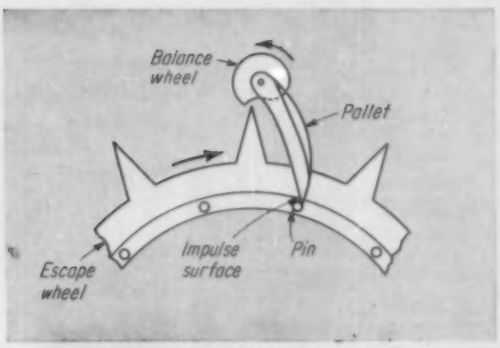
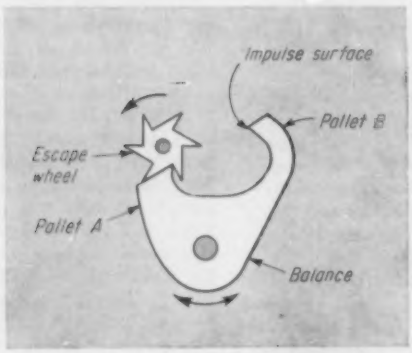
7 More Escapements continued



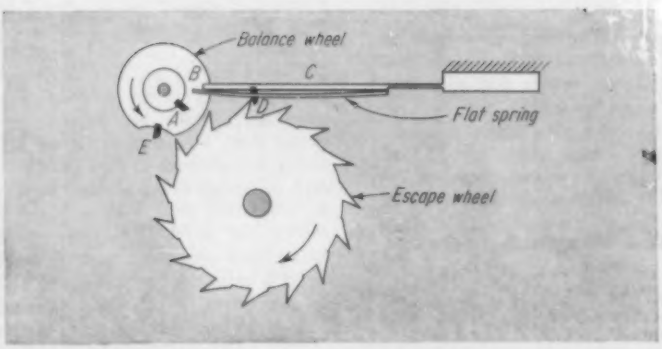
4 THREE-LEGGED. The three teeth of escape wheel work alternately upon top and bottom pallets. Top pallet is shown being driven to right. When tooth clears pallet, escape wheel will turn until tooth engages bottom pallet. When pendulum slide starts back toward left, bottom pallet will receive push from escape wheel, until tooth clears pallet.



5 DUPLEX. Single pallet of balance wheel is shown receiving impulse from pin of escape wheel. As balance wheel rotates counterclockwise, tooth of escape wheel clears notch, permitting escape wheel to turn clockwise. Next tooth of escape wheel is stopped by balance wheel until balance wheel reaches limit, reverses direction, and pallet swings back to position shown. Escapement receives but one impulse per cycle.

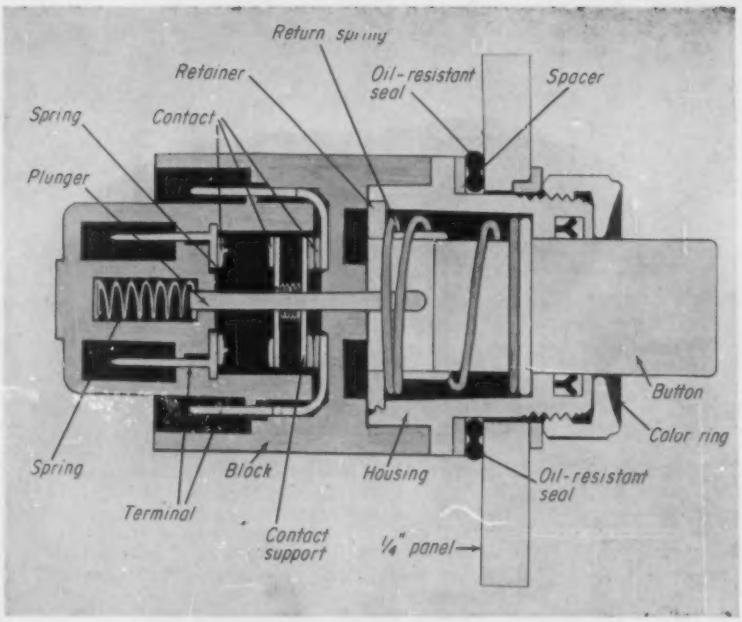


6 STAR WHEEL. Dead-beat escapement in which pallets alternately act upon diametrically opposed teeth. Illustration shows balance in extreme clockwise position with escape wheel locked. Balance starts turning counterclockwise, releasing escape wheel. At other extreme, pallet *B* locks escape wheel for a moment before direction of balance is again reversed and push is imparted.



7 CHRONOMETER. As balance wheel turns counterclockwise, jewel *A* pushes flat spring *B* and raises bar *C*. Tooth clears jewel *D* and escape wheel turns. A tooth imparts push to jewel *E*. As jewel *A* clears flat spring, jewel *D* returns to position and catches next tooth. On return of balance wheel (clockwise), jewel *A* passes flat spring with no action. Thus, escapement receives a single impulse per cycle.

SIGNIFICANT COMPONENTS MATERIALS, PROCESSES



Miniature, oil tight industrial pushbuttons . . .

require 40% min less space than heavy-duty units and may be mounted as close as 1¼ in. apart. Mounts in ⅞ in. dia mounting hole with locking notch. Included in line, which meets applicable JIC, NMTBA and NEMA standards, are mushroom head buttons, selector switches, illuminated pushbuttons, illuminated mushroom-head buttons, transformer-type indicating lights, and push-to-test indicating lights. Guarded or unguarded units are available. Retaining rings in six different colors permit color coding. Illuminated forms are also available in six colors. Engraved or blank nameplates can be supplied in two sizes. Pushbuttons utilize push-on pressure type terminals. Rated for 150 v ac max, 5 amp carry and 30 amp inrush at 115 v ac; 1.1 amp inductive make and break, at 125 v dc. From stock. Price is approximately the same as the firm's heavy-duty industrial switches. **General Electric Co, Schenectady 5.**

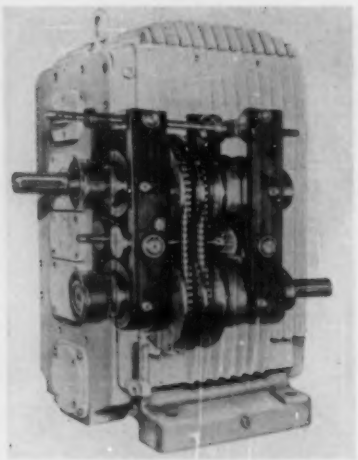
Circle 300 on Reader Service Card

Swash-plate engine . . .

can be driven from any source of pressurized gas or vapor and is rated at 100 shaft hp at speeds between 4000 and 5000 rpm. Unit is 12 in. long and 6½ in. dia, and was developed from units designed for undersea warfare. Available with shaft-hp ratings from 1 to 100 or more; deliver constant torque from stall to full speed.

Also available are high-pressure pumps for pumping noncorrosive and corrosive liquids. Pumps provide 1 gpm output at 2500 psi and 4000 rpm. Larger unit weighs 36.5 oz and is 3½ in. long, less shaft, and 2.75 in. dia. Swash-plate units were developed for handling various difficult fluids. **Clevite Ordnance, Div Clevite Corp, 540 E 105th St, Cleveland 8.**

Circle 301 on Reader Service Card



Variable-speed drives . . .

meet capacities up to 50 hp and ratios up to 5.5:1. Drives consist of twin strands of single-roll chain operating between pair of facing wheels with floating center disk. Effective diameters of wheel faces are altered during operation, changing ratio and output-shaft speed. In this way, they provide stepless adjustment between max and min setting on such equipment as heavy machine tools, timing, mixing, synchronizing and handling systems. Drives of 3.8:1 and less can be directly coupled to 1750-rpm motor. Available in five types: basic drive, basic drive with output gears, basic drive with input and output gears, basic drive with integral foot-type motor and basic drive with integral foot-type motor and output gears. **Link-Belt Co, Prudential Plaza, Chicago 1.**

Circle 302 on Reader Service Card

Teflon lip seal . . .

provides controlled amount of liquid injection into stuffing box to prevent abrasives in process fluids from reaching mechanical seal. Lip seal is installed in bottom of stuffing box bore. Split expansion collar locks lip seal in operating position. Sealing ring has interference fit around shaft. Clearance on OD of Teflon sealing ring allows it to float radially with shaft to prevent excessive wear. By injecting compatible clean flushing liquid into stuffing box at slightly higher pressure than process equipment pressure, flushing liquid is permitted to pass under Teflon lip into pump or processing equipment. This flow prevents abrasives in proc-

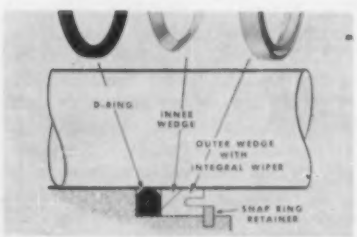
ess fluid from entering stuffing box. Amount of dilution passing into process is dependent upon differential pressure maintained between stuffing box injection liquid and process fluid of equipment. **Duratmetalic Corp, Kalamazoo, Mich.**

Circle 303 on Reader Service Card

Self-stripping wire connector

originally developed for telephone, communications and signalling industries is reported to splice, insulate and moisture-seal in up to one-third to one-half the time required for conventional twist-and-sleeve splices. Accommodates any two- or three-wire combination of No. 19 to No. 26 AWG solid or No. 20 to No. 26 AWG stranded wire, and handles all common types of insulation. Resulting splice is said to be functional equal of twist-and-solder jointing methods, with average pullout resistance equal to 95% of wire breaking strength. Connector is made of transparent thermoplastic material, filled with silicone grease, and incorporates metal, finger-like connector element. **Minnesota Mining & Mfg Co, 900 Bush Ave, St Paul 6.**

Circle 304 on Reader Service Card



Reciprocating-rod seal . . .

combines a rubber D-ring, nested inner-wedge nylon ring and nested outer-wedge nylon ring with integral rod wiper for use with hydraulic and pneumatic cylinders. D-ring element is available in various rubber compounds; nested backup wedge rings are made of plastic or metal. Inserted in counter-bore in cylinder head, seal assembly is secured with snap-ring retainer near cylinder head's outside surface. Operates with any fluid and at temperatures from —70 to 600 F. Available in standard sizes for rods from ¼ to 3 in. **Greene, Tweed & Co, North Wales, Penna.**

Circle 305 on Reader Service Card

Militarized synchronous motor

has torque of 150 in.-oz and constant-speed output of 72 rpm. Can be used as dc stepping or inching motor. Rated for input of 120 v, 40/70 cps, single phase, 0.4 amp max current at 60 cps. Weighs 6½ lb. Standard types are available with specially designed planetary-gear speed-reduction assemblies providing speeds of about 16.6, 3.3, 0.67, 0.133 or 0.027 rpm. Price, $64 without planetary gears. **Superior Electric Co, Dept SS, Bristol, Conn.**

Circle 306 on Reader Service Card

Motorized speed reducer . . .

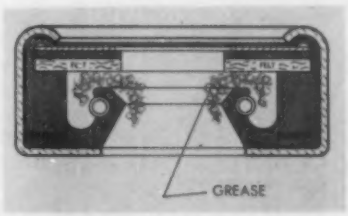
is worm-geared, horizontal parallel-drive model, powered by 1/20 hp or 0.035 hp motors. Provides output speeds from 1.9 to 70 rpm. Available from stock. **Boston Gear Works, Quincy 71, Mass.**

Circle 307 on Reader Service Card

Miniature incandescent lamp indicator . . .

is transistor-driven and operates with less than 1 ma input. Supplied with 24-v incandescent lamp, it operates on 12 v. Available with various lenses, colors, shapes and markings. Dimensions are 1.76 x 0.50 in. dia behind panel. **Eldema Corp, 1805 Belcroft Ave, El Monte, Calif.**

Circle 308 on Reader Service Card



Lip-type oil seal . . .

combines synthetic compound with built-in felt and rubber filter for applications where abrasive particles or other foreign matter must be sealed out of pumps. Replaces use of carbon ring, face-type seal in water pumps to 5 psi. With fluorocarbon face, seal handles up to 100 psi. Handles eccentricity of 0.01 and wobble of 0.02 without spring. Entire unit can be tubed for automation. Available in custom units in all sizes. Delivery, 1 wk to 10 days after tooling. Priced about 50% less than carbon ring face-type seal; with fluorocarbon face, price is about the same as carbon ring face-type seal. **International Packings Corp, Bristol, NH.**

Circle 309 on Reader Service Card

Solid-film lubricants . . .

operate without deterioration when exposed to nuclear irradiation of 1×10^7 to 1×10^8 roentgens at up to 550 F. Wear-life properties after exposure are reported to be increased by over 30%. Lubricants are also corrosion-resistant and lubricate efficiently in —65 to 1800 F. Friction and wear-life properties are said to meet Mil Spec 25504. **Electrofilm Inc, 7116 Laurel Canyon Blvd, North Hollywood, Calif.**

Circle 310 on Reader Service Card

Rate-of-change computer . . .

is self-contained and measures temperature changes directly from thermocouples, pressure changes from strain gages or resistance bulbs, neutron flux buildup in reactors, and measures and controls pH variations in processes. Priced at $450. Delivery, 45 days. **Magnetic Instruments Co, Thornwood, NY.**

Circle 311 on Reader Service Card

Metal alloy coating . . .

protects static metal seals in installations where liquid gases, such as liquid oxygen and exotic fuels, are used. Can be applied to corrosion-resistant steel, aluminum or any other metal seal. Suitable for use in temperatures of —300 to 650 F. Adhesion is reported to be excellent because it is achieved by creation of molecular rather than mechanical bond. Process is said to be competitively priced with Teflon coatings. **Harrison Mfg Co, 739 N Lake St, Burbank, Calif.**

Circle 312 on Reader Service Card

Miniature electrical actuator

provides mechanical power for emergency operation of switches, valves, and similar applications. Originally developed to meet military requirements, actuator is now available for commercial applications. Operates with input of 1.5 amp min at 20 v. Device releases initial mechanical force of 70 lb. Wide range of electrical and mechanical variations are offered. **Electro-Seal Corp, 946 A North Ave, Des Plaines, Ill.**

Circle 313 on Reader Service Card

Subminiature limit stop . . .

is size 5 unit that is adjustable over entire range from zero to 10 revolutions. Once set, unit will repeat its limit of travel to within 15 min. at rated torque. Setting and adjustment can be made at any time

continued on page 58

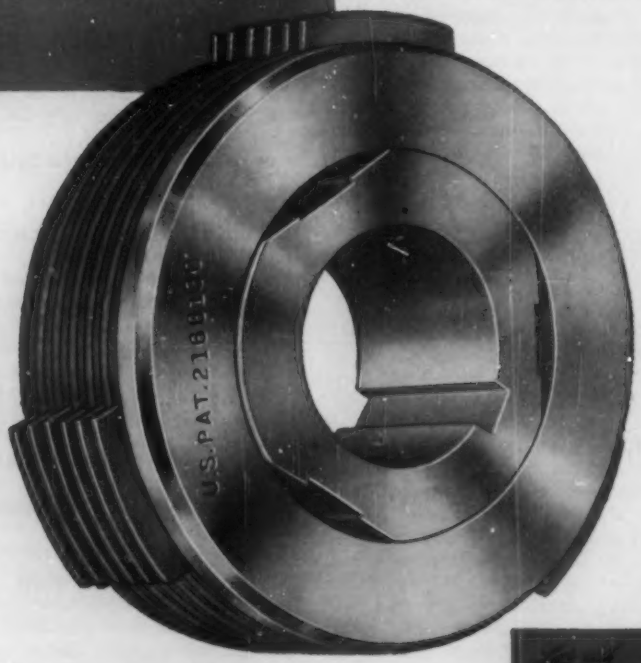
Maxitorq
Disc-pac

THE *Prepackaged* CLUTCH OR BRAKE ASSEMBLY

Takes performance guesswork out of power transmission design

With these performance-proved units, you can save time and money in designing and building clutches and brakes exactly tailored to the requirements of your application. At the same time, you can be sure that they will equal the performance and smooth operation of proved MAXITORQ clutches and brakes. DISC-PACS are simply the "heart" of a clutch or brake... the discs, separator springs, and locking plate... supplied as a complete self-contained unit for the convenience of design engineers and equipment builders.

Produced in a full range of sizes and capacities from ¼ h.p. to 15 h.p. Bulletins available on other MAXITORQ products: Floating Disc clutches and brakes, Electric clutches, Overload Release clutches, low-cost Single Disc clutches, and clutch or brake friction discs. Write Dept. PE.



THE CARLYLE JOHNSON MACHINE CO.
MANCHESTER, CONNECTICUT

3CJ60
58 CIRCLE 58 ON READER SERVICE CARD

or can be factory preset. Torque rating is 50 in.-oz; starting torque is 0.01 in.-oz. Operates in —85 to 257 F. Body and shaft are stainless steel; ½-in. case is anodized aluminum. Price is $25. Northfield Precision Instrument Corp, Port Washington, NY.

Circle 314 on Reader Service Card

Low-pressure relief valve . . .

is cartridge-type unit, which simplifies circuitry and can be removed for servicing without disconnecting lines. Direct operating valve has 10 to 500 psi operating range. Specific operating pressures are covered by three pressure ranges. Adjustments are made by external pressure-adjusting screw. Made of stainless steel and anodized aluminum, valve handles all fluids compatible with material used in construction. Weighs 6 oz. Fluid Regulators Corp, 313 Gillette St, Painesville, Ohio.

Circle 315 on Reader Service Card

Expanded-scale pressure transducer . . .

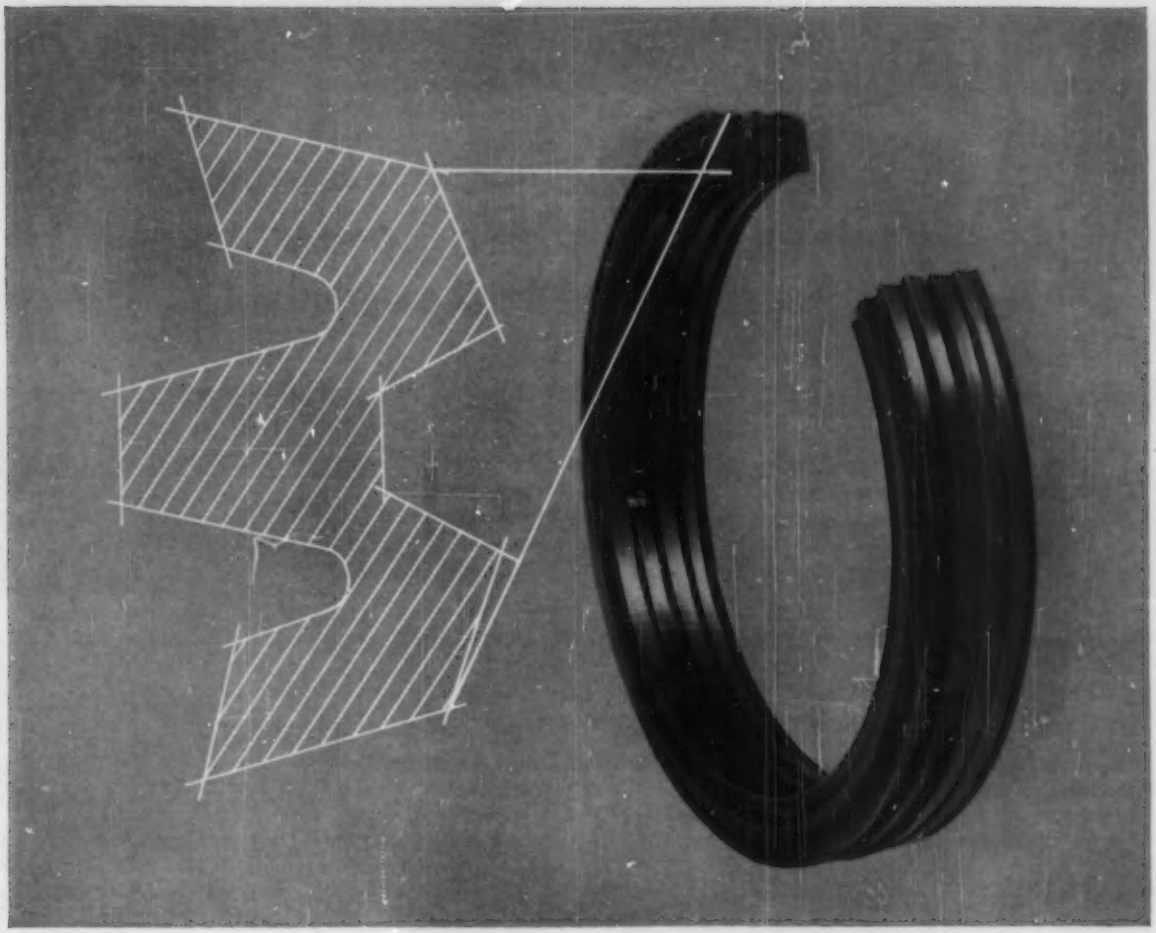
is particularly suited where interest lies primarily in upper end of rated range. Pressure transducer functions on specific portions of range, such as 475 to 550 psi. Full 0-5 v dc output is provided for this portion of range, rather than dissipating output in areas of no interest. Output requires no amplification. Accuracy is said to increase proportionally. Combined linearity and hysteresis is reported to be better than 0.15% of pressure. Wiancko Engineering Co, 255 N Halstead, Pasadena, Calif.

Circle 316 on Reader Service Card

Fast-drying contact cement...

bonds plywood to linoleum or hard sheet plastic, clad aluminum to plywood and hard sheet plastic to aluminum. Adhesive forms high-strength bonds immediately after assembly. Bond is resistant to water, oils, gasoline, heat and cold and will remain flexible at temperatures down to —40 F. Strength of bond increases with aging. Bonding operation can take place 10 min. to 4 hr after cementing of both surfaces. Cream-color, synthetic-rubber-

continued on page 62



Smaller stuffing boxes made possible with J-M UNEEPAC®

THIS UNIQUE CROSS-SECTION SHOWS WHY UNEEPAC AFFORDS FULLY AUTOMATIC SEALING IN LIMITED SPACE

Because Uneepac offers compact design and greater efficiency...smaller stuffing boxes and fewer rings are required to seal against the most rugged conditions!

These fully automatic, self-centering and self-adjusting packings are pressure-actuated. They are easy to assemble ... are quickly installed ... fit accurately ... reduce friction ... give exceptional service life in rod and piston applications.

Skillfully compounded in whatever materials best meet your requirements, J-M moulded packings are engineered with the workmanlike care and precision for which Johns-Manville is known throughout industry. They are specifically designed to give you top performance and optimum economy for every packings dollar you spend.

There is a broad selection of J-M moulded packings specifically engineered for hydraulic and pneumatic applications. A complete range of all standard sizes, styles and materials is available for immediate shipment. Or J-M will custom-make and design the exact packing that will give you the best, most economical service.

You'll find complete information in free booklets PK-126 A and PK-148 A, which present all J-M moulded packings materials and designs, with specific recommendations for most applications and service conditions. See your J-M Distributor. Or write to Johns-Manville, Box 14, New York 16, N. Y. In Canada: Port Credit, Ontario.

JOHNS-MANVILLE JM PRODUCTS

CIRCLE 59 ON READER SERVICE CARD 59

(*Advertisement*)

DOW | *Now in magnesium and aluminum*

NEW DOW DEVELOPMENTS PROVIDE DESIGNERS WITH ADDED ADVANTAGES IN LIGHTWEIGHT MAGNESIUM

Lightness, ease of fabrication and other features of magnesium contribute to improved designs for many products—from airplanes and missiles to luggage . . . from industrial machinery to cameras. Now, new developments by Dow provide greater design flexibility than ever before—in fabricated components you require, in materials and processes to facilitate your plant's operations.

New sheet is bent without heated dies.

NEW CLOSE SHEET TOLERANCES HELP SOLVE WEIGHT PROBLEMS

When the design problem is stress distribution versus weight, the new, closer magnesium sheet tolerances available from Dow upon special request offer a real advantage. As shown below, new tolerances are one *half* of standard tolerances. This permits designers to provide for required stress distribution, based on minimum thickness, *without* having to accommodate all the extra weight that might occur with the maximum thickness permissible with conventional tolerances.

Especially useful for aircraft and missile designers, this close tolerance sheet is also suggested for use in air-transported equipment or wherever minimum weight is critical.

COMPARISON OF TOLERANCES

48-inch-wide sheet

Gauge	Close Tolerances	Standard Tolerances
.032"	±.0013"	±.0025"
.040	±.0015*	±.003
.050	±.002	±.004
.063	±.002	±.004
.071	±.002	±.004
.080	±.002	±.004
.090	±.002	±.004
.100	±.0025	±.005
.125	±.0025	±.005
.160	±.004	±.008
.190	±.005	±.010

*For HM21A-T8 .040" close tolerance is ±.002".

NEW SPECIAL BEND SHEET ELIMINATES HEATED DIES

Critical bends can now be easily formed at room temperature — *without heated dies*—using Dow's new AZ31B-O Special Bend Sheet. Without cracking, it bends through an angle of 90° around a mandrel radius as small as two times the nominal sheet thickness. Among many suggested applications are housings for electronics equipment, truck cabs, shipping containers, plus such military uses as maintenance and personnel shelters and housings for ground support equipment.

BEND FACTORS

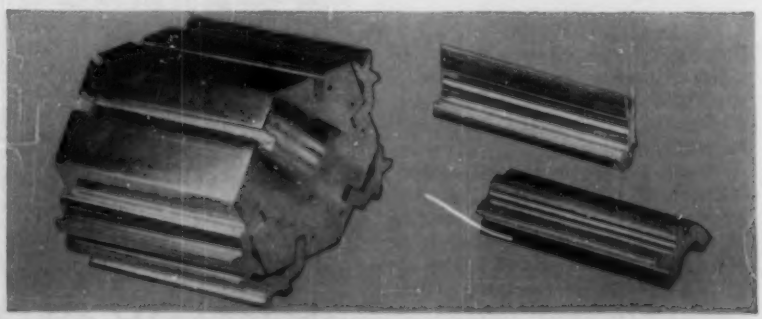
Nominal thickness	Longitudinal bend factor	Transverse bend factor
0.040"–0.100"	2.0	2.5
0.101"–0.190"	2.5	3.0

Tensile yield strength meets Federal Specifications AA-M-44.

PRECISION MAGNESIUM EXTRUSIONS CUT MACHINING COSTS

Dow precision magnesium extrusions provide exact-tolerance finished or semi-finished components and eliminate many costly multiple machining operations. Exacting tolerances are even possible with sharp V's, deep notches, thin slots, sharp serrations, as well as precision diameter tubing. And with precision extrusions, cost of materials is also frequently less because high-property alloys to withstand extensive machining are not needed.

Applications include bearing blocks, impact extrusion stock, parts for business machines, printing furniture, screw machine stock, shaft shear keys, spacers and airfoil configurations.



Exact-tolerance extrusions cut machining costs.

(Advertisement)

NEW FINISHES BROADEN APPLICATIONS FOR MAGNESIUM

Porcelain enamel, a practically foolproof way to avoid corrosion, can now be applied to magnesium, using a Dow-developed pretreatment to assure adhesion. Suggested applications—display signs, building panels, cooking ware, home appliances, engine parts.

Dow 20 chrome pickle provides a uniform paint-base for casting alloys with high aluminum content.

Dow 21 ferric nitrate bright pickle, as a spray or dip, provides long-lasting protection under clear baking enamels or lacquer.

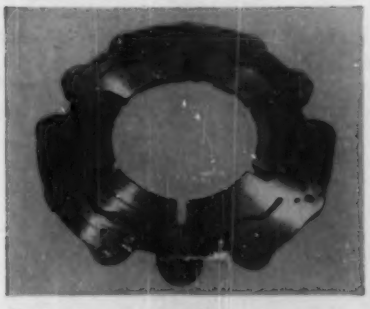
Clear anodic coating, applied in less than a minute, provides maximum protection under lacquer or varnish, which may be tinted in a wide range of colors.

Nickel plating, by immersion instead of electroplating, simplifies processing, improves nickel surface. For electronics equipment, printing plates and cylinders, other surfaces requiring extreme wear resistance.

Vinyl may be laminated before cold-forming magnesium sheets—also bonds to hot-formed shells. For luggage, carrying cases, other applications.

Vinyl-laminate adds sales appeal to carrying cases, luggage.

DOW CASTS MAGNESIUM IN INTRICATE DESIGNS



Casting incorporates tubeless passages.

Cast-in tubeless passageways, thin sections, close tolerances and other intricate designs are all available in castings made in production quantities at Dow's sand and permanent mold foundry.

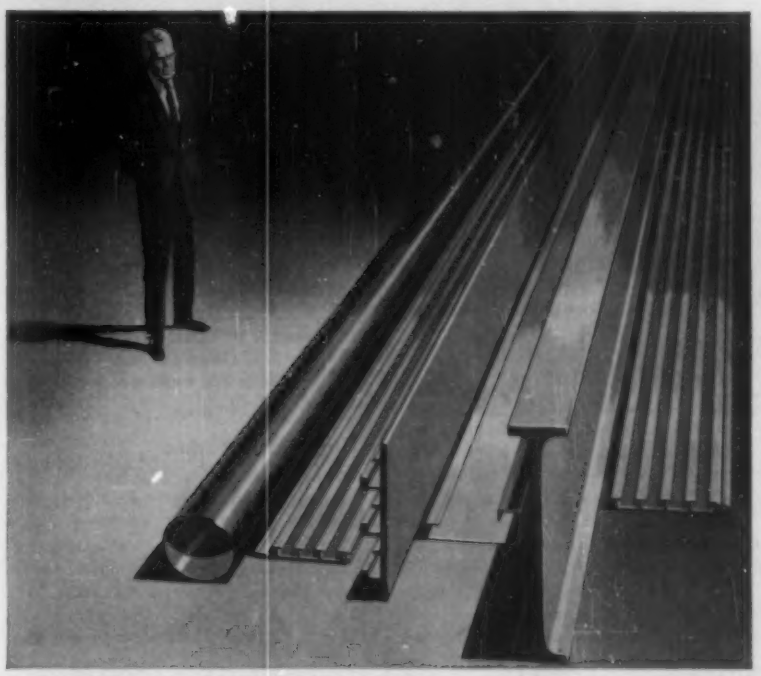
NEW ALLOY ELIMINATES STRESS RELIEF AFTER WELDING

A newly developed Dow alloy for magnesium sheet and plate, ZE10A, containing zinc and rare earth metal, does away with the need for stress relief after welding . . . particularly advantageous in building large structures. Suggested applications – large shipping and storage containers, even tank-trailer bodies. So that designers can take full advantage of this new sheet and plate material, Dow also provides magnesium extrusions in alloys requiring no post-welding stress relief.

VAST PRODUCTION FACILITIES FOR MAGNESIUM AND ALUMINUM

The Dow Metal Products Company offers a new die casting plant, a sand and permanent mold foundry, a fabrication plant plus the huge Madison plant for sheet, plate and extrusions. At Madison, for example, is the giant 13,200-ton press that extrudes king-size sections of magnesium or aluminum—up to 30 inches across and 80 feet long.

For more information about the new magnesium developments shown here, or for help in any design or fabrication problem involving magnesium or aluminum, contact the nearest Dow sales office. Or write THE DOW METAL PRODUCTS COMPANY, Midland, Michigan, Merchandising Department 1053DZ6-27.



King-size extrusions make possible freedom in design.

THE DOW METAL PRODUCTS COMPANY

Division of The Dow Chemical Company

CIRCLE 61 ON READER SERVICE CARD 61

base adhesive is supplied in 1-qt, 1-gal, 5-gal and 55-gal containers. One gal will cover about 200 sq ft. **Schwartz Chemical Co Inc, 50-01 Second St, Long Island City 1, NY.**

Circle 317 on Reader Service Card

Self-orienting synchronous motor . . .

in sub-fhp size has rotor that synchronizes at same relative position with respect to rotating stator field. Rotor orients within 5°. No dc excitation of rotor is required. Motor is two-phase, 60-cps, 115-v ac unit; 400-cps designs are available. Housing measures 1¾ in. dia x 2 in. long. Weighs 10 oz. Synchronizing torque is 0.50 in.-oz and torque is 0.65 in.-oz. **Kollsman Motor Corp, Dublin, Penna.**

Circle 318 on Reader Service Card

Multiple-layer filter . . .

removes matter as small as 1 micron from oil, coolant and hydraulic lines and filters up to 300 gph. Fluids pass through multiple layers of diatomaceous-earth powder and fine-mesh Monel screw. Unit is 12 in. high and 9 in. dia. Weighs less than 10 lb. **Wire Cloth Products Inc, 2801 Congress St Expressway, Bellwood, Ill.**

Circle 319 on Reader Service Card

Silicone O-rings . . .

seal difficult fluids are resistant to swelling normally caused by solvents, jet fuels and oils. Provide seals for fluids in low temperatures to 450 F and higher. Shore hardness rating is 70 to 75. Dry-heat resistance of O-ring is said to be among best of available silicone-rubber compounds. **Stillman Rubber Co, 5811 Marilyn Ave, Culver City, Calif.**

Circle 320 on Reader Service Card

Adjustable-torque friction clutch . . .

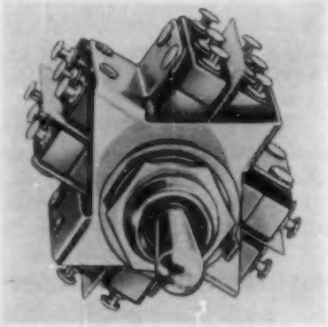
dissipates heat through one-piece cast iron hub and pressure plate. Built-in slippage provision protects equipment against overloads beyond torque setting, rather than relying on failure of some part to protect driving and driven equipment. As soon as overload is removed, clutch returns to positive drive and connected equipment goes back into operation. Range of standard sizes is offered. **Vickery Div, Norwalk Tool and Die Inc, 52 Woodlawn Ave, Norwalk, Ohio.**

Circle 321 on Reader Service Card

4-in.-high panel wireway . . .

is available in 1-, 1½-, 2- and 3-in. widths. Size meets JIC requirements and modular panel wireway has increased wire-holding capacity. Top, bottom and sides are independent and sections may be purchased individually. Can be installed without base by spacing sides, in width desired, on panel. **ECP Corp, 4726 Superior Ave, Cleveland 3.**

Circle 322 on Reader Service Card



Four-way toggle switch . . .

has 8PDT contacts. Assembly is made up of four pairs of Series 5300 snap-action switches with electrical ratings at 5 amp resistive; 3 amp inductive at 30 v dc and 115 v ac. From center position it is possible to actuate DPDT circuitry in each of four momentary positions, spaced 90° apart. Dimensions are $2\frac{5}{32}$ x $1\frac{31}{64}$ in. Weighs 0.11 lb max. Operating force is 0.5 lb. Price is $31.50 each in quantities of 1 to 25. **Haydon Switch Inc, Waterbury 20, Conn.**

Circle 323 on Reader Service Card

Fast silicon-mesa switcher . . .

offers dc beta ranges of 20 to 60; charge-storage-time constant of 25 nanoseconds max; output capacity from 6 to 5 pf; turn-in time of 40 nanoseconds max; turn-off time of 75 nanoseconds max; min BV_{CEO} of 15 v at sustaining current of 10 ma; max $I_{CER\ (RBE=100\ K)}$ of 10 microamp at 20 v V_{CE}. Currently available up to quantities of 999. **Texas Instruments Inc, PO Box 312, Dallas 21.**

Circle 324 on Reader Service Card

Ballbearing slide mechanism . . .

for use in electronic cabinets, features quick-disconnect pivot, extruded aluminum slides. The 90° up/down pivoting of chassis-holding section facilitates detachment of chassis from rack. **Jonathan Mfg. Co, 720 E Walnut St, Fullerton, Calif.**

Circle 325 on Reader Service Card

¼-in., 4-way solenoid valve

has forged-brass body, with ¼ or ⅜ in. pipe connections, and poppet-type seats and disks. Main valve disks are power-driven in both directions without aid of return springs. Said to be practically instantaneous

in operation, valve operates on air, water or hydraulic oil at pressures to 250 psi and 212 F. Mounts in any position. Combination of metal to metal and resilient seating provides tight seating on air and liquids without grinding or adjustments. **Automatic Switch Co, Florham Park, NJ.**

Circle 326 on Reader Service Card

Lever and tee handles . . .

are for use on variety of doors, including cabinets, machinery, electronic equipment and panel boards. Locking handles have five- and six-disk tumbler mechanisms. All handles are pressure-cast and have standard satin-chrome finish. Standard spindles are cadmium-plated and are ⅜ in. long from back of escutcheon. Handles permit one, two or three point locking. Standard keying makes possible 200 different key changes. Optional left- or right-hand operation, 90 or 180° rotation. **Corbin Cabinet Lock Div, American Hardware Corp, New Britain, Conn.**

Circle 327 on Reader Service Card

Fluted grips on knobs . . .

and handwheels for heavy-duty and high-torque clamping devices, adjusting rods, valves and regulators are produced from

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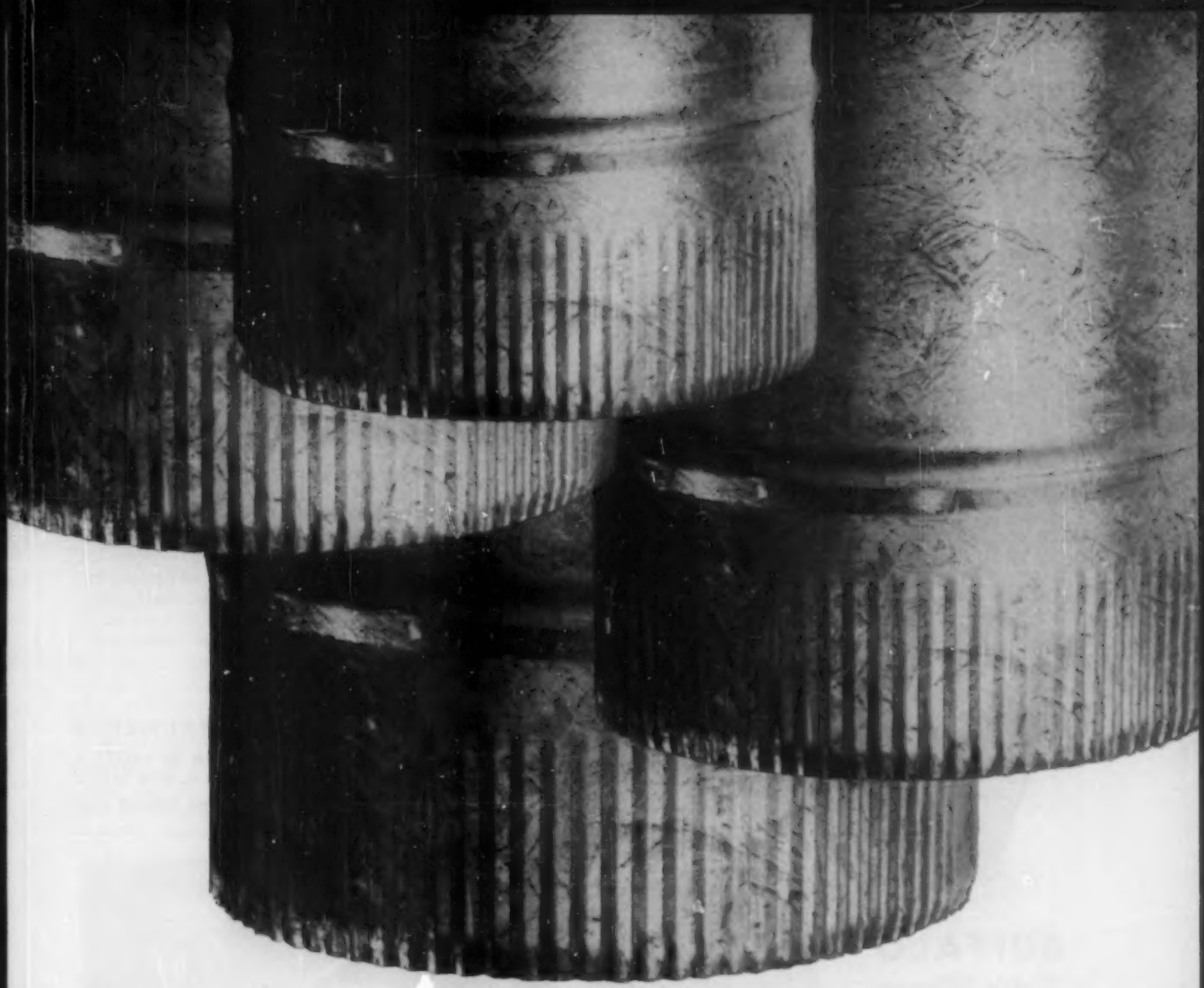

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stock molds. Both knobs and handwheels are 2⅜ in. OD and available with plain cored holes, tapped brass inserts and protruding studs. Knobs, with ½ in. longer hub than the handwheels, can also be obtained with reamed brass bushings and setscrews for ¼ to ½-in. dia shafts. Black phenolic is standard material, but parts are offered in many phenolic and urea colors. Dimco-Gray Co, 207 E 6th St, Dayton 2, Ohio.

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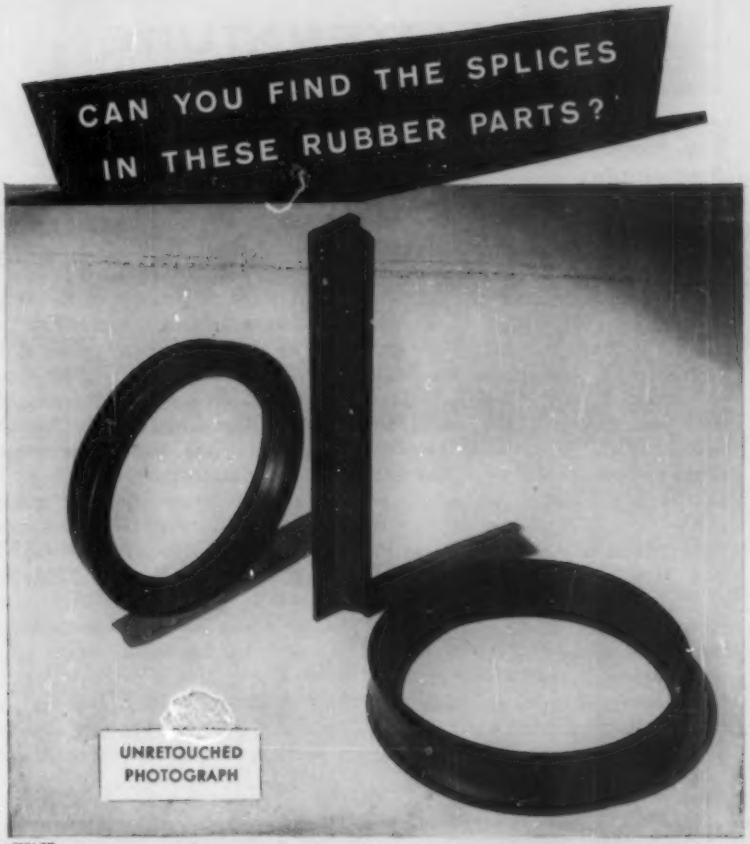

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DESIGN LITERATURE

The Modern Aspect of Mathematics

LUCIENNE FELIX. Basic Books Inc. 59 Fourth Ave, New York 3. 6¼ x 9½, 195 pp. $5.

To the mathematician, mathematics is a philosophical science in which even the most fundamental arguments are suspect. The engineer finds this world of thought strangely foreign; by training, he is accustomed to think of mathematics only as a rigid, thoroughly practical tool. This book is an introduction to latest thoughts in this field of science where "one and one do not equal two unless rigorously proved."

Miss Felix is a French mathematician connected with a revolutionary society known as the Bourbakists. Nicolas Bourbaki, leader of the movement, does not exist. He is the whimsical invention of French mathematicians who, wishing to give their theories stature and cohesiveness, sign his name to their work adding their own name under the title of "devoted secretary" or "faithful adjutant."

The Bourbakists approach mathematical inquiry from two basic standpoints: general algebra and general topology. General algebra is more abstract, more simple and, at the same time, more difficult to grasp than the algebra we know. The questions it asks and the conclusions it draws seem absurd and obvious, yet that is its goal; to dig further down into the foundation rather than climbing perilously out on the superstructure.

General topology is a kind of geometry developed under the same variety of reasoning; more fundamental, yet more recondite than the Euclidian form. It wrestles with puzzlers such as the four-color map problem (not yet proved): Are four colors always sufficient if it is desired to shade irregularly divided areas in a plane surface such that colors on opposite sides of a common boundary are different? To promote their theories, the mathematicians have fashioned an elaborate set of symbols; some of these will seem strange to engineers, others show their heritage from symbolic logic.

Though originally written in French, Miss Felix's translators give us a clear exposition of these new forms of mathematics and the first semi-popular book on the Bourbakist revolution. Not a reference for the library of a practical engineer but a stimulating thought-provoker for those who take their mathematics with a measure of scientific skepticism. —CJL

Centrifugal-pump Application Manual (second edition, 1959)

Edited by BRUCE W ELLIS. Buffalo Pumps, Div of Buffalo Forge Co, Buffalo, NY. 4½ x 6½, 279 pp. $5.

This concise and useful handbook is a compilation of theory and application data to acquaint users with all types of centrifugal pumping equipment. Starting with principles of pump operation, it covers a broad range of liquids and slurries under widely differing conditions imposed by industry's requirements today.

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Other Books of Interest

Machine Tapers

American Standard ASA B5.10-1960. American Society of Mechanical Engineers, 29 W 39th St, NY 18. 8½ x 11, 33 pp, $2.50.

High-temperature Technology

McGraw-Hill Book Co Inc, 330 W 42nd St, NY 36. 8¾ x 11¼, 348 pp, $15.

Proceedings of an international symposium held in Monterey, Calif, Oct 6-9, 1959.

Basic Research Resumes

PB 161291. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 x 10½, 342 pp, $5.

A survey of basic research activities of the Air Research and Development Command.

ASTM Standards on Plastics

American Society for Testing Materials, 1916 Race St, Philadelphia 3. 6 x 9¼, 1242 pp, $9.

Conversion Tables

European Technical Coverage Inc, 75 E Wacker Drive, Chicago 1. 4 x 5¾, 48 pp, $2.56.

For conversion of US and British units into metric and vice versa.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover. For those catalogs and bulletins available only when requested on company letterhead, see page 70.

RELAYS—Catalog 1960 C-10, 64 pp. Presents over 20 leading relay manufacturers' lines with descriptions and prices. Table of contents is thumb-indexed. Relay Sales Inc, Box 186, W Chicago, Ill.

Circle 340 on Reader Service Card

MAGNET WIRE—Publication WC-8289, 50 pp. Covers product descriptions with dimensional and application information. Selection guide includes various available types of wire. Nomograms are included for computing cross-sectional areas, resistance, and weight of rectangular conductors, together with information on varnish properties, types and application, and radiation effects. General Electric Co, Wire and Cable Dept, Bridgeport 2, Conn.

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LIQUID-RELIEF AND SPECIAL-SERVICE VALVES—Catalog FE-138, 28 pp. Describes and illustrates line of valves with sizing information, capacity tables, weights

continued on page 69

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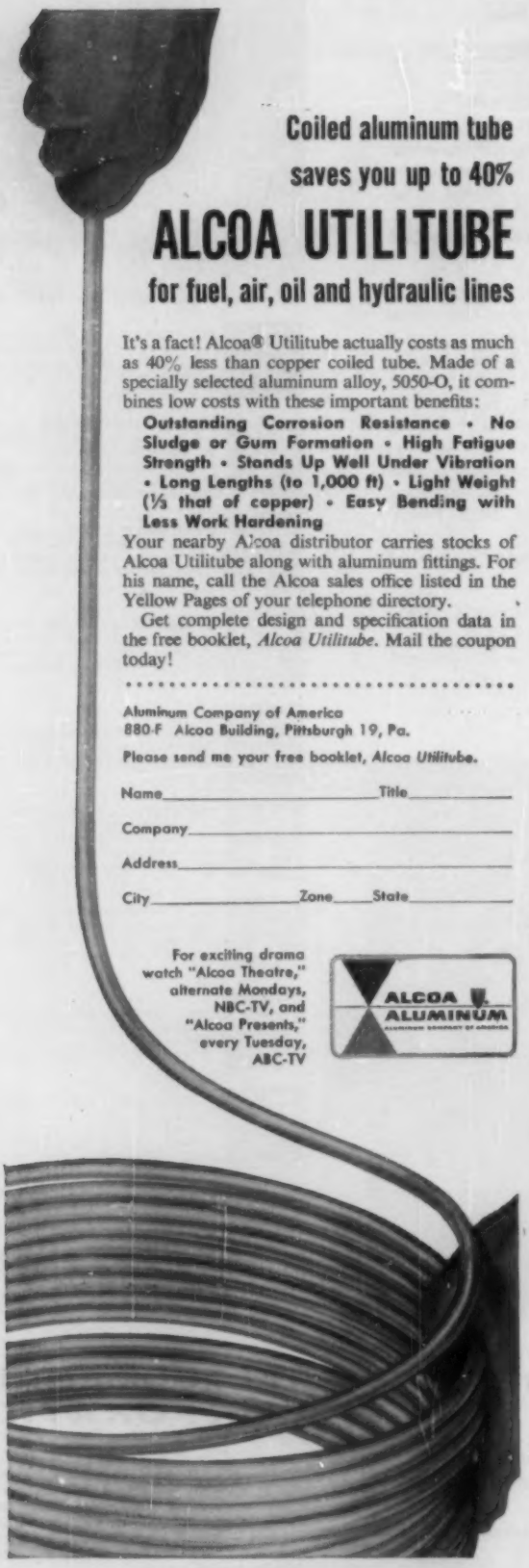

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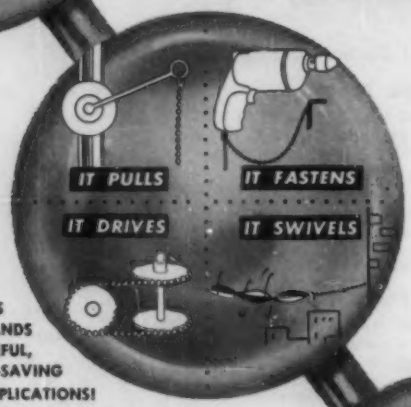

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and dimensions and application information. Farris Engineering Corp, 705 Commercial Ave, Palisades Park, NJ.

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STOCK SPRINGS—Catalog 101-1960-61, 20 pp. Lists over 750 springs, available for immediate delivery. Contains specifications and price sheet for all sizes. Lee Spring Co, Div of Leetronics Inc, 30 Main St, Brooklyn, NY.

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ROTARY MULTIPOLE SWITCH — Bulletin 19, 2 pp. Information on type JK rotary switch. Includes photo, dimensional drawings, specifications and special-assemblage drawings. Electro Switch Corp, King Ave, Weymouth 88, Mass.

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SNAP-ACTION SWITCHES — Catalog 560, 16 pp. Features precision snap-action switches and electromechanical devices. With characteristics and ratings. Cherry Electrical Products Corp, 1650 Deerfield Rd, Highland Park, Ill.

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SEALS AND FASTENERS — Catalog 359A, 16 pp. Specifications, dimensions and characteristics of high-pressure, vibration-resistant seals and fasteners, self-grounding power connectors and products made from a transparent material with properties of silicone rubber. APM Corp, 252 Hawthorne Ave, Yonkers, NY.

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COIL PRODUCTS—Catalog CP-100, 28 pp. Gives electrical and physical specifications on over 600 units, as well as application information. Includes 79 schematics covering every coil type in general use. Chicago Standard Transformer Corp, 3501 W Addison St, Chicago 18.

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MODULAR PLASTIC DIFFUSER—Catalog 460, 36 pp. Contains sound ratings, performance data and specifications of three types of modules that provide infinite number of air patterns, sizes for air distribution. Carnes Corp, Verona, Wis.

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LAMINATING GUIDE—Booklet, 24 pp. Recommends materials, equipment and production techniques for users of laminating surfaces based on diallyl phthalate resin. Dapon Dept, Food Machinery and Chemical Corp, 161 E 42nd St, New York 17.

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COLORED BALLPOINT PENS—Booklet, 16 pp. Lists more than 150 ballpoint and liquid-graphite pens, which have been rated according to ability to provide sharp reproductions when used with copying machines. Minnesota Mining & Mfg Co, 900 Bush St, St Paul 6.

Circle 350 on Reader Service Card

VARIABLE-SPEED SHEAVE—Bulletin 6102, 8 pp. Revised bulletin provides additional technical information and new list prices. T B Wood's Sons Co, Chambersburg, Penna.

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SQUARE POTENTIOMETERS — Data sheet 60271, 4 pp. Power input charts, electrical and mechanical specifications, standard coil data and modifications available on ½-in. square-trimming potentiometers. With photos and outline drawings. Helipot Technical Information Service, Helipot Div of Beckman Instruments Inc, 2500 Fullerton Rd, Fullerton, Calif.

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SUBMINIATURE SEALED LIMIT SWITCHES—Data sheet 171, 2 pp. Includes circuitry, electrical ratings and mechanical characteristics of 400EN series. With diagrams and photos. Micro Switch, Freeport, Ill.

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MULTIDECK ROTARY THUMBWHEEL SWITCH—Catalog sheet, 2 pp. Specifications and dimensions of 8-, 10-, 12- or 16-position rotary thumbwheel switch. Chicago Dynamic Industries Inc, Precision Products Div, 1725 Diversey Blvd, Chicago 14.

Circle 354 on Reader Service Card

ELECTROSEALING PROCESS—Manual AA, 8 pp. Explains basic steps and applications for hermetic sealing of electromechanical components and assemblies. Electro-Seal Corp, 946 A North Ave, Des Plaines, Ill.

Circle 355 on Reader Service Card

WELDED-STEEL TUBING—Reference weight chart, 4 pp. Contains weight chart and listing of tolerances for square and rectangular welded-steel tubing. Standard Tube Co, 24400 Plymouth Rd, Detroit 39.

Circle 356 on Reader Service Card

PRECISION INSTRUMENTS AND COMPONENTS—Condensed catalog A-26, 4 pp; catalog sheet, 1 p. Catalog briefly describes bridges and accessories, decade voltage dividers, decade resistors, decade capacitors and computers. Fly sheet covers impedance bridges. Electro Scientific Industries, 7523 SW Macadam Ave, Portland 19, Ore.

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AIR-HYDRAULIC INTERCHANGEABLE BOOSTERS—Engineering guide

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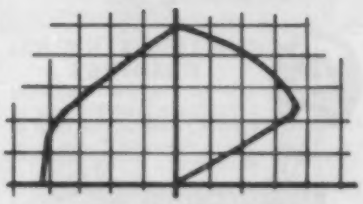

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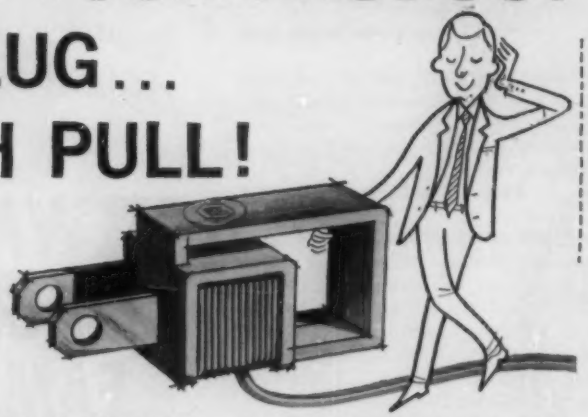

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116, 14 pp. Covers ranges of uses, background information on actual booster operation, hydraulic pressure and flow data, and features. Includes tables for calculating thrust force and displacement and pull-stroke force and displacement and selection charts for boosters and cylinders. S-P Mfg Corp, 30201 Aurora Rd, Cleveland 39.

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TAPE TRANSPORT—Bulletin DS-3170A, 4 pp. Specifications, application information and features of Series 3170 magnetic tape transports. Flutter curve is included. Minneapolis-Honeywell Regulator Co, Industrial Systems Div, 10721 Hanna St, Beltsville, Md.

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SURGE PROTECTORS—Bulletin EPD 3135-1, 4 pp. Covers nine standard types from 50 to 600 v normal-peak inverse voltage rating, and includes construction features, performance characteristics and typical circuit applications. Vickers Inc, Electric Products Div, 1815 Locust St, St Louis 3.

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SINGLE - PHASE LINE - VOLTAGE REGULATORS—Bulletin AC610, 4 pp. Covers use of three single-phase ac regulators in three-phase circuits with input in four-wire Y and outputs in delta or Y. Sorenson & Co, S Norwalk, Conn.

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FOOTSWITCHES—Bulletin, 2 pp. Styling, service and electrical ratings are covered for six models. Linemaster Switch Corp, 432 Woodstock Terr, Woodstock, Conn.

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COPOLYMERS—Technical note sheet, 1 page. Covers temperature ranges, properties, resistance of Viton copolymer materials used for sealing to such materials as aromatic solvents, aliphatic hydrocarbons, oils and a number of oxidizing materials. Various copolymers and elastomers in which Viton is a principal component are discussed and general applications are mentioned. Stillman Rubber Co, 5811 Marilyn Ave, Culver City, Calif.

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LETTERHEAD REQUEST ONLY

Manufacturers who published following literature asked that requests for copies be made on company letterheads.

ELECTRONIC PRODUCTS — Catalog, 288 pp. Lists and provides specifications for hundreds of products and systems. Catalog is separated into several categories, such as electron tubes, electronic instruments, industrial systems and microwave instruments. Hoffman Electron Tube Corp, 804 Newbridge Ave, Westbury, NY.

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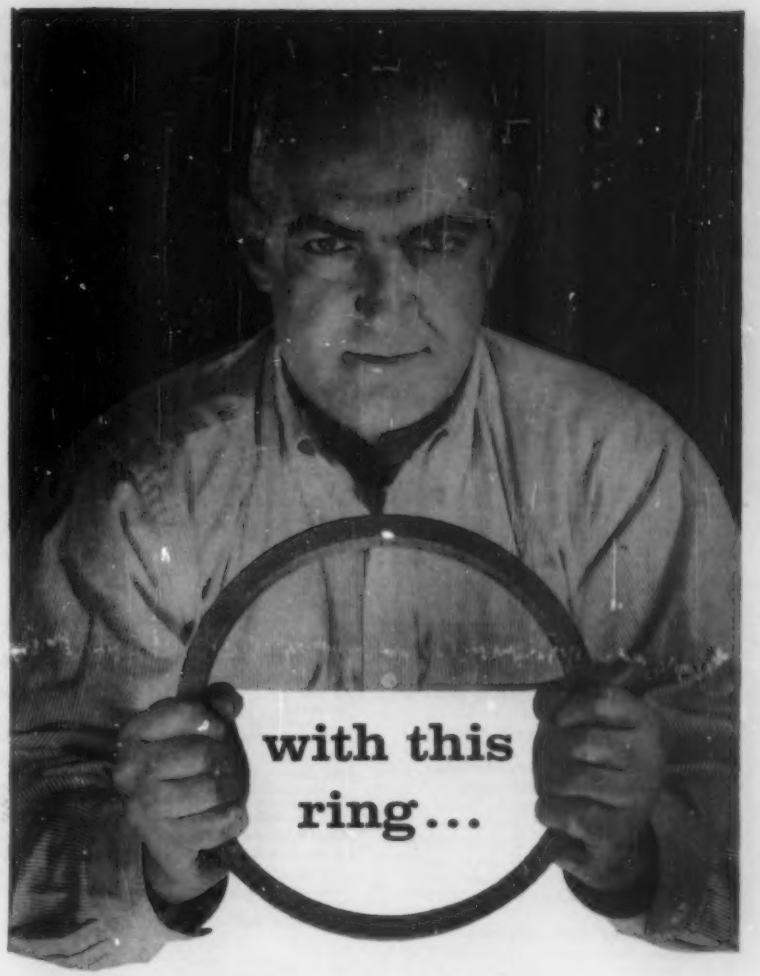

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GENERAL ELECTRIC

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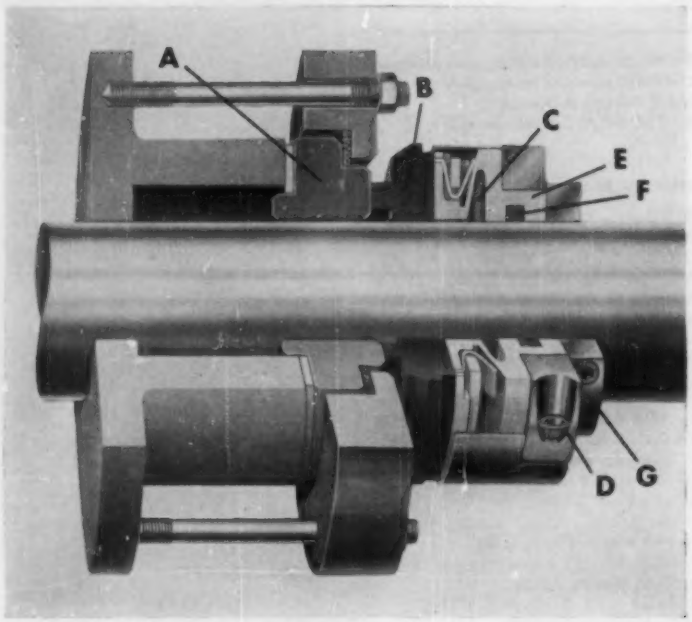

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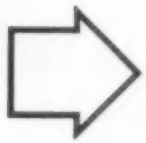

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5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
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7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

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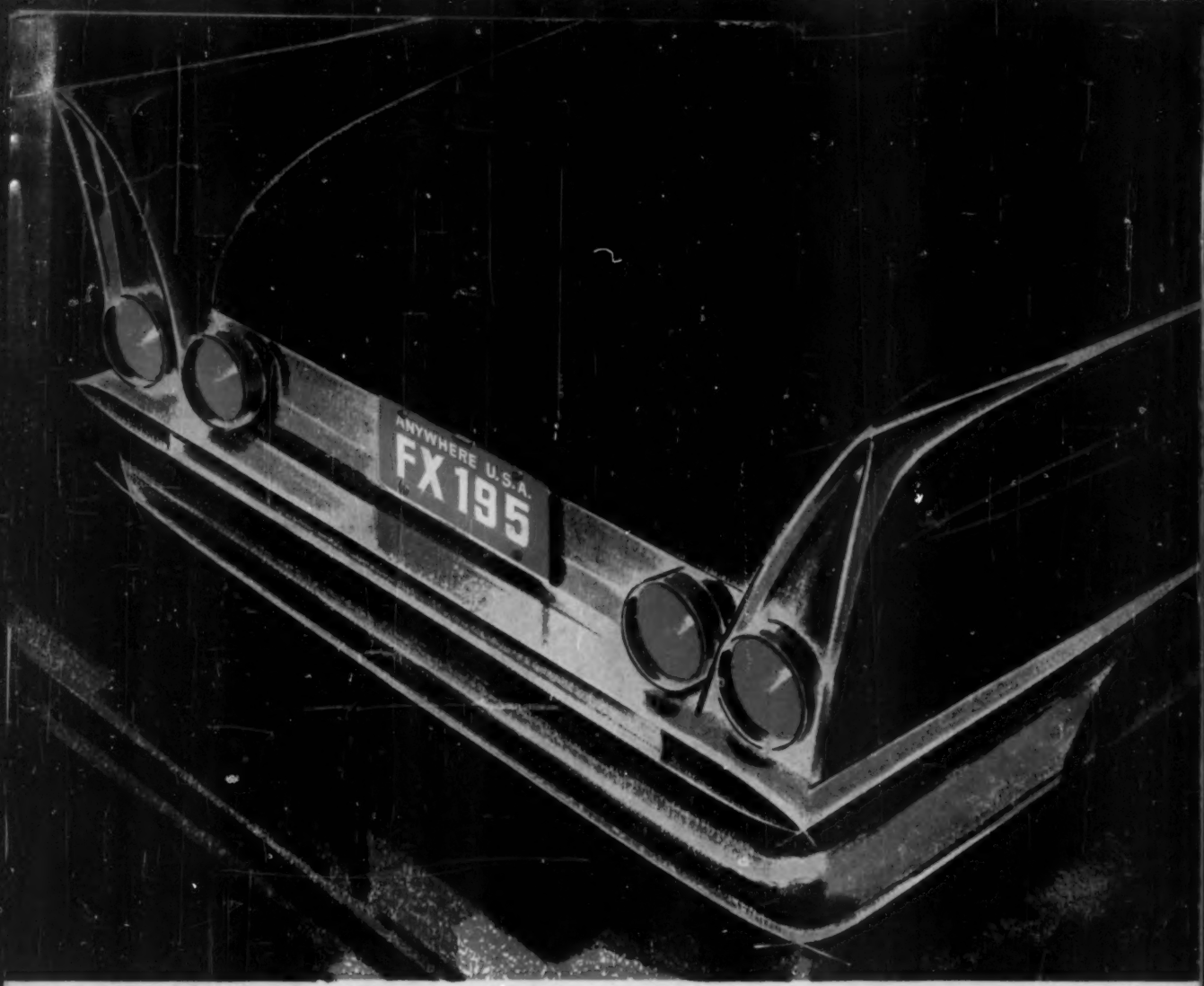

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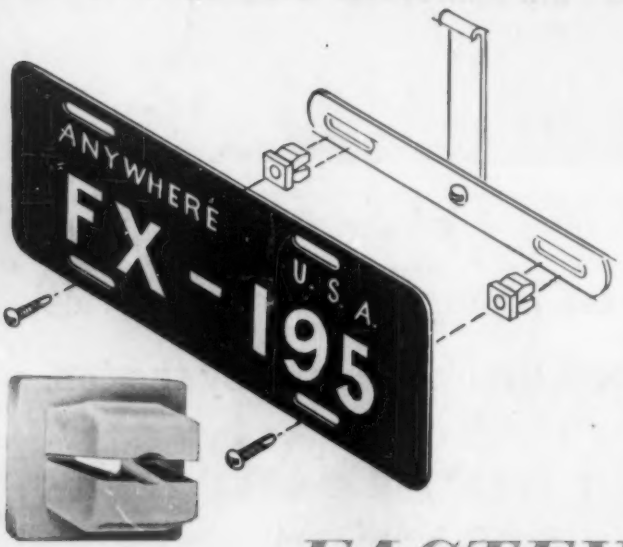

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